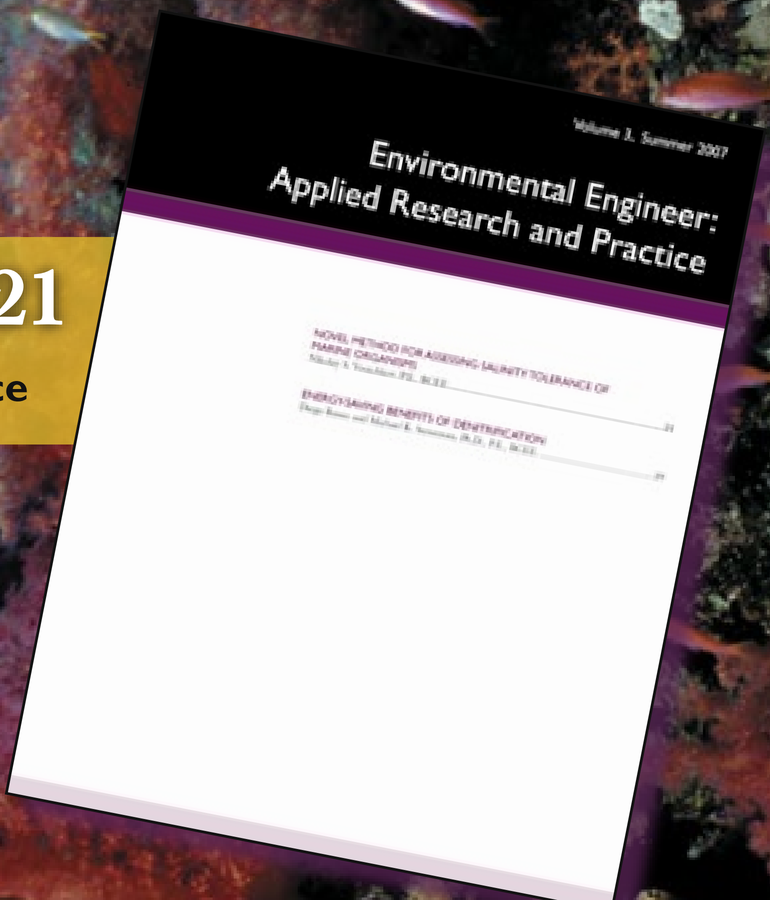
THE MAGAZINE OF THE AMERICAN ACADEMY OF ENVIRONMENTAL ENGINEERS®

ENVIRONMENTAL ENGINEER

VOLUME 43 NUMBER 3 — SUMMER 2007



Volume 3, Summer 2007

Environmental Engineer: Applied Research and Practice

NOVEL METHOD FOR ASSESSING SALINITY TOLERANCE OF MARINE ORGANISMS

ENERGY-SAVING BENEFITS OF DENITRIFICATION

ENVIRONMENTAL ENGINEER

BY STEPHEN R. KELLOGG, P.E., BCEE

CAMPAIGN 4000

AT OUR RECENT BOARD OF TRUSTEES MEETING, YOUR BOARD UNANIMOUSLY PASSED THE ACADEMY'S FIRST EVER FIVE YEAR STRATEGIC PLAN. It is a blueprint for growth designed to double the size of the Academy over the next five years. In a survey of the membership this objective was identified as a high priority so that AAEE could continue programs like Board Certification of Environmental Engineering professionals, the Engineering Excellence Awards, ABET accreditation essential to ensuring the quality of future environmental engineering graduates, academic outreach to engineering students, career placement assistance, and increasing environmental engineering's profile in our society.

This Strategic Plan was first mentioned in the Winter 2007 issue of the Environmental Engineer on the President's Page entitled "Moving Forward". In the Spring 2007 issue this same topic was discussed in a message entitled "Funding the Plan." AAEE is stronger in terms of membership and finances than it has been in more than a decade. We have asked for help from the membership historically through difficult times. Many of you responded and helped us keep the business of AAEE ongoing. We are now operating from a stronger foundation and with a vision.

Campaign 4000 is required to provide AAEE with a reserve to fund the tools necessary for upgrading our communication systems, academic outreach, hosting local and regional meetings, and promoting the value of Board Certification to the engineering community. It is a one-time campaign with a goal of raising $150,000 over three years. The first ten percent of this goal has been achieved by pledges from your Board of Trustees . The mechanism for funding is a three-year pledge of $333 per year for a total of $1,000. While the commitment by each individual contributor is relatively modest, the impact to an organization like AAEE is very significant. The Academy operates with a very limited budget, modest staffing, and a lot of volunteer effort.

If successful, the campaign will seed the growth required to implement our plan. A growth in new membership at a rate that doubles our membership to 4000 will result in a strong cash surplus negating the need for additional future supplemental funding. New members at these levels will result in cash surpluses exceeding 10% to 20% of our annual budget. Healthy and viable organizations make an impact through sustainable growth. This pledge will allow the Academy to secure our future and increase our outreach.

The American Academy of Environmental Engineers has been in existence for over 50 years. AAEE has accomplished many things and implemented some excellent programs for the profession. This bold initiative and commitment on your part will secure our future in fulfilling the promise that the founding fathers intended, "to achieve excellence in the practice of environmental engineering to ensure the public health, safety, and welfare to enable humankind to co-exist in harmony with nature." There has never been a stronger environmental need to fulfill this promise with major global challenges. The best vehicle to meet these challenges is utilization of highly qualified Board certified professionals.

Please sign the Donation/Pledge form (on page 6 or download from our website at http://www.aaee.net) and make your personal impact on this mission. My commitment to you is that your President and Board of Trustees will utilize this investment wisely through increasing membership and expanding our programs so that the investment results in long-term sustainability for both AAEE and recognition of our profession. Very few investments at this level have the potential to make such a significant impact on our environment and way of life. Thank you for your support. A

ENVIRONMENTAL ENGINEER

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www.aaee.net

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ACADEMY NEWS

2007 AAEE ANNUAL MEETING

AAEE will hold its 52nd Annual Board of Trustees Meeting on Friday, November 2 in Cambridge, Massachusetts. Registration packages have been mailed to Officers & Trustees, Committee Chairs and State Representatives. All members of the Academy are welcome to attend.

CHANGES TO MEMBERSHIP CATEGORIES

The BCM (Board Certified Member) membership category title has been changed to BCEEM (Board Certified Environmental Engineering Member) as of October 1, 2007.

The BCM to BCEEM change was necessitated by the requirement of the Council of Engineering and Scientific Specialty Boards (CESB), the body that accredits the Academy's certification program, that all specialty certification titles are descriptive of the specialty that is being certified. Current BCM holders will be issued new certificates designating the new title.

2008 KAPPE LECTURER

Jeanette A. Brown, PE, BCEE is the 2008 Kappe Lecturer. Ms. Brown is currently Executive Director of the Stamford Water Pollution Control Authority and President of the Environmental and Water Resources Institue of the ASCE. A biography and abstract of her lectures will appear in a future issue of *Environmental Engineer*.

SPECIALTY CERTIFICATION RENEWAL

The 2008 Certification Renewal has been mailed to the membership. It is important that it be completed and returned with payment as soon as possible and definitely before December 31, 2007. It is important to get corrections on your Member Data Form to us no later than December 31, 2007, to ensure those changes are printed in the 2008 edition of *Who's Who in Environmental Engineering*.

2008 EXCELLENCE IN ENVIRONMENTAL ENGINEERING COMPETITION®

Begin planning your entry now. Deadline for entries is February 1, 2008.

In 2007, the AAEE E3 Competition for 2007 introduced a new entirely electronic submission process. Participants noted that the electronic process made entry submittals easier. Because judging was also done entirely electronically, AAEE was able to select from a wider range of judges. For details for submitting entries for 2008 and viewing past winners, look for details on our website at http://www.aaee.net.

FALL *ENVIRONMENTAL ENGINEER*

The Fall issue of the *Environmental Engineer* will feature the Farkas Berkowitz & Company's annual State of the Industry Report. Also, the cover story will be AAEE's Five-Year Strategic Plan.

ENVIRONMENTAL ENGINEER: APPLIED RESEARCH AND PRACTICE

The Winter 2007 issue of *Environmental Engineer* introduced *Environmental Engineer: Applied Research and Practice*. AAEE has continued to get praise on the journal.

Journal Editor C. Robert Baillod, Ph.D., P.E., BCEE, along with the Editorial Board (listed on page 22), would like to encourage authors to submit their papers, particularly those focused on practical research and use case studies related to environmental engineering. Submittal guidelines are on page 23.

Campaign 4000
Donation/Pledge Form

Yes! I would like to contribute to Campaign 4000 to fund the AAEE 5-Year Strategic Plan to foster the sustained growth and progress of the Academy.

NAME

STREET ADDRESS

CITY STATE ZIP

PHONE E-MAIL

ORGANIZATIONAL AFFILIATION

☐ **PLEDGE: $1,000.** *Payment will be made over a period of 3 years.*

☐ **OTHER: $**________ *Payment will be made over* _______ *year(s).*

☐ **CHECK ENCLOSED.** Check number _______
Please make your check out to AAEE Campaign 4000 and mail to:
American Academy of Environmental Engineers
130 Holiday Court, Suite 100
Annapolis, MD 21401

☐ CHARGE TO: _______VISA _______ MasterCard

CARD NUMBER EXPIRATION DATE

CARDHOLDER SIGNATURE *Mail charge information to AAEE or fax to 410.266.7653*

Thank you for your financial support in helping the AAEE sustain its continuing growth.

HEDY V. ALAVI, PH.D., P.E., BCEE, is the recipient of "The 2007 Johns Hopkins University Alumni Association Excellence in Teaching Award" for the Whiting School of Engineering. Dr. Alavi has been certified in Solid Waste Management since 1998.

JAMES L. BARNARD, PH.D., PR.ENG., BCEE, has been named the NWRI 2007 Clark Prize Honoree, presented at the Fourteenth Annual Clarke Prize Lecture and Award Ceremony. The Clarke Prize was established by NWRI in 1993 to recognize outstanding research scientists in the areas of water-science research and technology. Dr. Barnard is the 2006 AAEE Honorary Board Certified Environmental Engineer.

RAYMOND C. LOEHR, PH.D., P.E., BCEE, was selected as recipient of the 2007 Lifetime Achievement Award, presented at World Environmental & Water Resources Congress. Dr. Loehr has been certified in Water Supply & Wastewater Engineering since 1975.

JOHANNES B. NEETHLING, PH.D., P.E., BCEE, has been named Program Manager for the core team of the WERF Nutrient Challenge. WERF selected HDR to manage the five-year program, which will identify and pursue areas for cutting research in nutrient removal. Dr. Neethling, Vice President of HDR Engineering, Inc., has been certified in Water Supply & Wastewater Engineering since 1993.

GEORGE TCHOBANOGLOUS, PH.D., P.E., BCEE, is the 2007 recipient of the Frederick George Pohland Award, presented at the AEESP meeting in July. Dr. Tchobanoglous has been certified in Water Supply and Wastewater Engineering since 1987.

PAUL H. WOODRUFF, P.E., BCEE, received the 2007 Civil and Environmental Engineering Distinguished Alumni Award for the Michigan State University College of Engineering, his alma mater. Mr. Woodruff has been certified in Sanitary Engineering since 1968. A

Correction:

In the article, *Class of 2006* (Winter 2007, Volume 43, Number 1), the new Board Certified Environmental Engineering Members were incorrectly accredited as holding a P.E. license. They are:

Michael D. Aitken, Ph.D., BCEEM
Pratim Biswas, Ph.D., BCEEM
John F. Ferguson, Ph.D., BCEEM
John G. Harris, BCEEM
Hilary Inyang, Ph.D., BCEEM
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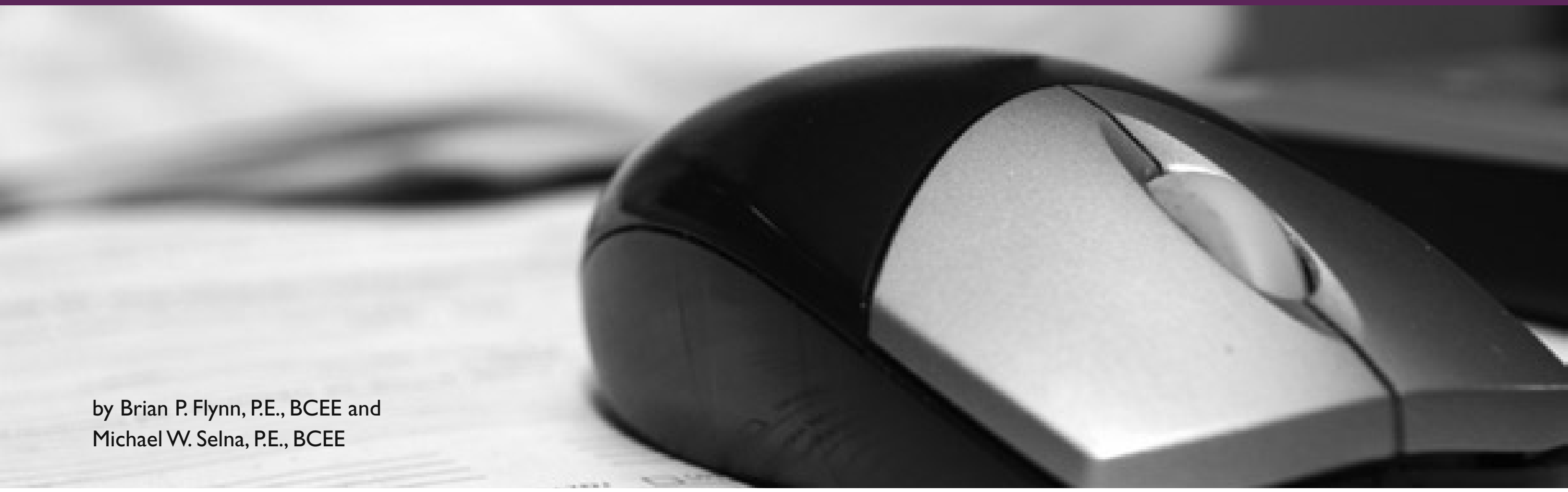
SPECIAL REPORT:

The Academy's Survey of the Membership



by Brian P. Flynn, P.E., BCEE and
Michael W. Selna, P.E., BCEE

The Academy created, in the fall of 2006, a Planning Committee to develop a Five Year Strategic Plan to cover the period of January 1, 2008 through December 2012. The Committee developed a list of goals for the Academy. These goals would involve, by and large, new initiatives. We then asked the question: "Are there any goals that would be unpalatable to the membership?" In order to find out, we embarked on the first ever internet survey of all the members. We received 441 responses.

A summary of results is shown in Table 1. The members showed very strong support for educational activities, creation of demand for the credential, broadening the organization to be a home for environmental engineers, and getting more academic involvement and members. There is strong support for developing the Body of Knowledge for Environmental Engineering curricula. Support for expansion of this magazine to include peer reviewed technical articles was not so strong- although it has occurred since the time of the survey. Opposition to this initiative seems to center on it as a duplication of effort with other organizations. The editorial board of the magazine has tried to avoid that by focusing on papers in the niche of hands-on, real world type environmental engineering applications. The readers can judge for themselves whether this is working.

Expanding the scope of the Academy and doubling its size had strong, but not overwhelming support. A number of comments focused on diluting the Academy's

TABLE 1
Summary of Survey Results: Academy Goals

Goal	Strongly Agree or Agree	Disagree or Strongly Disagree	Neutral
Promote Education (K-12 Science and Math and Higher Education)	89%	4%	7%
Conduct Workshops and Seminars	86%	4%	10%
Create Demand for Certified Environmental Engineers	83%	5%	11%
Promote Greater Involvement and Membership of Academics	82%	3%	15%
Expand Tau Chi Alpha	81%	4%	15%
Broaden Scope to Become Primary Home for Environmental Engineers	80%	7%	13%
Develop Body of Knowledge for Environmental Engineering Programs	72%	6%	22%
Expand Scope of Academy	57%	15%	28%
Upgrade the Magazine to Include Peer-Reviewed Technical Articles	57%	24%	19%
Double the Size of the Academy	50%	13%	37%
Promote the BCM Classification to non-PEs	30%	46%	24%

standards in the pursuit of greater numbers. The Planning Committee did not believe that to be the case: doubling from 2300 members to 4600 would still leave us with only 4-5% of the population of environmental engineers in the US. This is still a pretty exclusive group. Certainly the top 4 or 5% of environmental engineers is a very talented group, capable of meeting our high standards. We probably can't get many of them if we do not expand the Academy's scope beyond certification, engineering competitions, and some educational initiatives. If we can come anywhere near the goal of doubling in size in the next 5 years, it will provide the revenue for a significant expansion of services and activities of direct interest to members.

Promotion of the new BCM classification to non-PEs had weak support. It was the only goal that fell in this category. This classification was created to attract highly qualified Environmental Engineering professors and practitioners in industry. These are two important sectors which unfortunately do not emphasize engineering licensure. Indeed one of them (industry) generally is exempt from the need to do so. Professors have the ability to put students into the certification pipeline early in their careers. Industry is a huge user of environmental engineering services and sector in which the Academy is underrepresented. Clearly, the Academy and its membership have work to do in this area.

The survey also probed in depth the member's opinions about the purpose and potential venues for Academy sponsored workshops and seminars. The membership was highly in favor of associating such activities with larger organizations such as AWWA and WEF. This is the basic starting approach that has been adopted in the Strategic Plan. Members thought that workshops and seminars would enhance our visibility, but were more skeptical of their potential money-making capability.

We also asked the membership to rate the Academy's sensitivity and awareness level on cultural and gender differences in activities, publications, governance etc. Fully 62% of the membership felt that the Academy was neutral in this area with 32% rating the Academy as most sensitive or somewhat sensitive and 6% rating the Academy as somewhat insensitive or most insensitive. It appears that we have some work to do in this area as the Strategic Planning Committee would like to encourage more qualified women and minorities to join AAEE.

We also asked if the Members would like to work on any issues in the survey or serve on a Committee. 19% said yes (84 people) but on a related question, 142 members gave us their email address to serve as volunteers. We are currently working on putting those members to use on Academy activities.

We also accumulated 139 open-ended comments, both good and bad, from survey responders. A sampling is shown in Table 3. The comments show a lot of interest and a lively debate on some issues. They also indicate the Academy may need both to do more education of members on some issues and take the more helpful comments to heart.

In summary, the internet survey found no "showstoppers" in the proposed goals of the Strategic Plan, helped provide better focus for the nascent workshop and seminar activity and pointed out some interesting practical steps for the Academy to take. A

TABLE 2
Summary of Survey Results: Workshops and Seminars

	Strongly Agree or Agree	Disagree or Strongly Disagree	Neutral
Purposes			
Enhance AAEE Visibility in Profession	88%	1%	11%
Help Increase Membership	72%	6%	22%
Generate Income	50%	11%	39%
Venues			
Associated with Other Organizations Like WEF or AWWA	84%	7%	9%
Conduct as Regional One Day Events	71%	7%	22%
Combine with Excellence in Environmental Engineering Awards	49%	20%	31%

TABLE 3
Written Comments From Survey Responders

"I believe there are currently adequate educational opportunities elsewhere. AAEE focus should not be education."

"I think stand alone seminars are needed to provide the visibility the organization desires and that should promote a membership increase."

"AAEE should consider an annual national conference."

"AAEE should sponsor courses to obtain professional development credits, PDC's for maintaining our state PE licenses."

"The BCEE approach is long overdue in my opinion. Good to see it."

"I personally do not like the BCEE designation and prefer DEE."

"As an engineer who is female, I think that cultural/gender sensitivity is an overrated issue, and merit should be the key."

"We went through the expansion phase… and nearly went broke."

"More emphasis is needed to increase membership."

" …setting a goal of doubling the membership in 5 years may compromise the quality of the membership."

"The Academy should look at ways to certify allied professionals…"

"Glad to see a progressive outlook by the Academy."

"The AAEE certification program performs a vital role for environmental engineers."

"The Academy is making a strong statement by developing a five-year Strategic plan."

Academy Contributors

The American Academy of Environmental Engineers is pleased to recognize these individuals who contributed to several Academy fund during the 2006 certification renewal process. The total contribution to each program or fund are:

General Fund – $9,815.00
Environmental Engineering Foundation – $5,795.00
Environmental Engineer Magazine – $1,760.00
Excellence in Environmental Engineering – $1,935.00
Kappe Lecture – $1,190.00

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Robert F. Schwartz	Watching, NJ
Edgar F. Seagle	Rockville, MD
Stephen J. Sebesta	Strongsville, OH
Paul R. Shea	Merrimack, NH
Timothy G. Shea	Chantilly, VA
Thomas J. Sorg	Cincinnati, OH
Patricia D. Spence	Indianapolis, IN
Vernon T. Stack	Coatesville, PA
Prescott A. Stevens	Switzerland
Roger V. Stephenson	Pasadena, CA
Albert H. Stevenson	Towson, MD
Frank E. Stratton	Eastsound, WA
Ash Sudhakar	Railto, CA
Scott M. Summers	Rochester, NY
James N. Tarr	Rolling Hills Estates, CA
J. Dwight Thompson	Cincinnati, Ohio
Lial F. Tischler	Round Rock, TX
Eugene T. Tonn	Jacksonville, FL
N. C. Vasuki	Dover, DE
Jose F. Velazquez	Denver, CO
Ronald M. von Autenried	Park Ridge, NJ
Alfred T. Wallace	Moscow, ID
George Mack Wesner	San Clemente, CA
Maurice West	Lakewood, CO
C. Leslie Wierson	Portland, OR
Robert C. Williams	Norcross, GA
Charles A. Willis	Charlotte, NC
David Wohlschied	Vienna, VA
Melvin Wolkstein	Springfield, NJ
Donald J. Wuerdeman	Sierra Madre, CA
Yuefeng Xie	Middletown, PA
James C. Young	Fayetteville, AR
Jehangir Zakaria	Virgin Islands
Kent E. Zenobia	Sacramento, CA
Hooshang Zeyghami	Weston, WI

Kappe Lecture

William M. Auberle	Flagstaff, AZ
Michael Barbachem	Virginia Beach, VA
Richard D. Brady	Sacramento, CA
Edward H. Bryan	Chevy Chase, MD
Charles A. Buescher	Chester Field, MO
Jeffrey J. Chen	Palo Alto, CA
Wayne F. Echelberger	Tampa, FL
Matthew J. Flanagan	Westmont, NJ
Davis L. Ford	Austin, TX
Michael D. Hungerford	Edwardsville, IL
Hilary I. Inyang	Charlotte, NC
Michael C. Kavanaugh	Emeryville, CA
Ulf M. Lindmark	Long Beach, CA
Charles Liu	Dix Hills, NY
Cecil Lue-Hing	Burr Ridge, IL
Stephen F. McGowan	Schaumburg, IL
C. Eric Mulkey	Oak Ridge, TN
Charles F. Niles	Haines City, FL
Parnell O'Brien	Homer Glen, IL
Serin R. Rao	Mapleton, IL
Seymour J. Ryckman	Dayton, OH
James M. Symons	Bradenton, FL
C. Joseph Touhill	Jamison, PA
R. Rhodes Trussell	Pasadena, CA

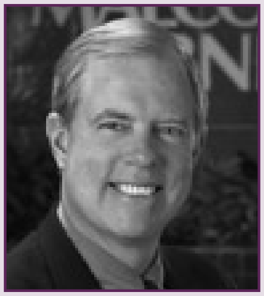
N. C. Vasuki .... Dover, DE
Alfred T. Wallace .... Moscow, ID
Robert W. Wheeler .... Morgantown, WV
Ira L. Whitman .... East Brunswick, NJ
Yuefeng Xie .... Middletown, PA
James C. Young .... Fayetteville, AR
George A. L. Yuen .... Honolulu, HI

Environmental Engineering Foundation

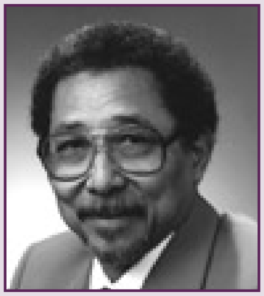
Walter Amory .... Duxbury, MA
Laura Andrews .... Bradenton, FL
Donald B. Aulenbach .... Clifton Park, NY
Kashinath Banerjee .... Moon Township, PA
Sanat K. Barua .... Worthington, OH
Curt B. Beck .... Pampa, TX
Richard W. Bentwood .... Glendora, CA
Robert A. Berndt .... Raleigh, NC
William F. Blank .... Decatur, IL
Richard H. Bogan .... Seattle, WA
Richard D. Brady .... Sacramento, CA
Edward H. Bryan .... Chevy Chase, MD
James T. Canaday .... Fredericksburg, VA
A. Dayton Carpenter .... Charleston, WV
Peter R. Charrington .... Wayne, PA
Michael R. Cline .... Indianapolis, IN
Paul W. Clinebell .... Mahomet, IL
Richard A. Conway .... Charleston, WV
Harold M. Cota .... San Luis Obispo, CA
John H. Cunningham .... Tinton Falls, NJ
John W. Curtis .... Milwaukee, WI
Anthony J. DeFalco .... Radnor, PA
Donald O. Dencker .... Sun Prairie, WI
Herman A. Dharmarajah .... Mankato, MN
Richard J. Fahey .... New York, NY
Kenneth G. Ferguson .... Anderson Island, WA
Jerome F. Fladung .... Shawnee Mission, KS
Matthew J. Flanagan .... Westmont, NJ
William L. Fletcher .... Warner, NH
Randall L. Foulke .... Raleigh, NC
Robert R. Goodrich Jr. .... Morristown, NJ
Stephen P. Graef .... Greenville, SC
Robert G. Gross .... Beaufort, SC
Alberto F. Gutierrez .... Dallas, TX
James R. Hagan .... Philadelphia, PA
Robert D. Hennigan .... Skaneateles, NY
Leonard L. Holt .... Santa Rosa, CA
Sam Jeyanayagam .... Columbus, OH
Yosh Katsura .... Ventura, CA
Richard W. Klippel .... Liverpool, NY
Karl F. Kohlhoff .... Gilbert, AZ
William E. Korbitz .... Thornton, CO
Paul A. Kuhn .... Lake Tomahawk, WI
Edward A. LaBahn .... Dana Point, CA
Richard F. Lanyon .... Chicago, IL
J. Leonard Ledbetter .... Kennesaw, GA
Jaeyon Jay Lee .... Carmel, IN
Ulf M. Lindmark .... Long Beach, CA
Charles Liu .... Dix Hills, NY
Raymond C. Loehr .... Lansdowne, VA
Stephen F. McGowan .... Schaumburg, IL
Shyam S. Mohanka .... Schenectady, NY
Richard A. Molongoski .... Latham, NY
C. Eric Mulkey .... Oak Ridge, TN
Robert L. Nichols .... Webb City, MO
Gerald Palevsky .... Hastings on Hudson, NY
Lawrence E. Peirano .... Lafayette, CA
Robert R. Perry .... Falls Church, VA
Serin R. Rao .... Mapleton, IL
Abdul S. Rashidi .... La Verne, CA
Leroy C. Reid Jr. .... Anchorage, AK
Elmo A. Richardson Jr. .... Macon, GA
Myong Ho Ro .... City of Industry, CA
Peter P. Rogers .... Cambridge, MA
August T. Rossano .... Redmond, WA
Jon M. Rueck .... Silver Lake, KS
Henry G. Schwartz .... St. Louis, MO
David L. Sheridan .... Camp Hill, PA
Shinji Soneda .... Honolulu, HI
Leo H. Stander .... Cary, NC
Michael K. Stenstrom .... Los Angeles, CA
David G. Stephan .... Cincinnati, OH
Morton Sterling .... Farmington Hills, MI
Albert H. Stevenson .... Towson, MD
John R. Stratford .... Roseburg, OR
Ash Sudhakar .... Rialto, CA
August John Szabo .... Lafayette, LA
Robert S. Trotter .... St. Charles, IL
Warren R. Uhte .... Mill Valley, CA
John J. Vasconcelos .... So. Pasadena, CA
N. C. Vasuki .... Dover, DE
Ronald M. von Autenried .... Park Ridge, NJ
Alfred T. Wallace .... Moscow, ID
Horton Wasserman .... Wilton, CT
Howard M. Way .... Alamo, CA
Leo Weaver .... Greeley, CO
Robert W. Wheeler .... Morgantown, WV
Robert L. White .... San Clemente, CA
Ira L. Whitman .... East Brunsswick, NJ
Charles A. Willis .... Charlotte, NC
Paul H. Woodruff .... Exton, PA
L. Carl Yates .... Fayetteville, AR

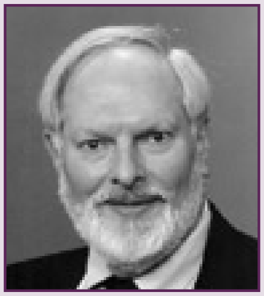
2 ♦ 0 ♦ 0 ♦ 8 Election Results

The Ballots have been counted. While the results will not be official until the Annual Meeting when the Teller's Report is confirmed by the Board, the following individuals have been elected for 2008. Current President-Elect William P. Dee will succeed to the Office of the President; Debra R. Reinhart will be President-Elect; Cecil Lue-Hing has been voted as Vice President; and Gary S. Logsdon and C. Robert Baillod have both been voted as Trustee-at-Large.


William P. Dee


Debra R. Reinhart


Cecil Lue-Hing


Gary S. Logsdon


C. Robert Baillod

2007 Tyler Prize

Gatze Lettinga

Emeritus Professor
Wageningen University
Sub-department of
Environmental Technology
Wageningen, The Netherlands

Tyler Prize

The Tyler Prize was established in 1973 by the late John and Alice Tyler as an international award honoring achievements in environmental science, policy, energy and health of worldwide importance conferring great benefit on humanity. The Tyler Prize consists of a cash award of $200,000 and a gold Tyler Prize medallion.

The Tyler Prize Executive Committee announces the awarding of the 2007 Tyler Prize for Environmental Achievement on its thirty-fourth anniversary to Prof. Dr. Ir. Gatze Lettinga, Wageningen University, The Netherlands.

Gatze Lettinga is recognized for his research and development of an environmentally sound novel process for the treatment of polluted wastewater and its implementation worldwide, especially in developing countries. Web: www.uasb.org/discover/agsb.htm

Recent Laureates

2000	John Holdren, for Energy & Public Policy
2001	Jared Diamond and Thomas E. Lovejoy, for Conservation Biology
2002	Wallace S. Broecker, for Ocean Chemistry and Tungsheng Liu, for Paleoclimatology
2003	Sir Richard Doll, Hans Herren and Yoel Margalith, for Environmental Medicine and Public Health
2004	The Barefoot College and Red Latinoamericana de Botánica (RLB), for Environmental Education
2005	Charles David Keeling and Lonnie G. Thompson, for Atmospheric Chemistry and Glaciology related to Climate Change
2006	David W. Schindler and Igor A. Shiklomanov, for Natural and Human Impacts on Freshwater Resources

For Additional Information and Nominations Contact:

Dr. Linda E. Duguay
Executive Director, The Tyler Prize
Phone (213) 740-9760,
Fax (213) 740-1313
Email: tylerprz@usc.edu
Home page www.usc.edu/tylerprize

The Tyler Prize is administered by
The University of Southern California

Members of the Tyler Prize Executive Committee

Dr. Owen T. Lind, Chair, *Baylor University*
Dr. Rosina M. Bierbaum, *University of Michigan*
Dr. Robert A. Frosch, *Harvard University and Woods Hole Oceanographic Institution*
Dr. Arturo Gómez-Pompa, *University of California, Riverside and Universidad Veracruzana*
Dr. Judith E. McDowell, *Woods Hole Oceanographic Institution*
Dr. Ralph Mitchell, *Harvard University*
Dr. F. Sherwood Rowland, *University of California, Irvine*
Dr. Jonathan M. Samet, *The Johns Hopkins University*
Dr. Cornelius W. Sullivan, *University of Southern California*

2006 FINANCIAL STATEMENT

INDEPENDENT AUDITORS' REPORT

We have audited the accompanying statements of financial position of American Academy of Environmental Engineers (a non-profit organization) as of December 31, 2006 and 2005, and the related statements of activities and cash flows for the years ended. These financial statements are the responsibility of the Academy's management. Our responsibility is to express an opinion on these financial statements based on our audits.

We conducted our audits in accordance with auditing standards generally accepted in the United States of America. Those standards require that we plan and perform the audit to obtain reasonable assurance about whether the financial statements are free of material misstatement. An audit includes examining, on a test basis, evidence supporting the amounts and disclosures in the financial statements. An audit also includes assessing the accounting principles used and significant estimates made by management, as well as evaluating the overall financial statement presentation. We believe that our audits provide a reasonable basis for our opinion.

In our opinion, the financial statements referred to above present fairly, in all material respects, the financial position of American Academy of Environmental Engineers as of December 31, 2006 and 2005, and the changes in its net assets and its cash flows for the years then ended in conformity with accounting principles generally accepted in the United States of America.

MULLEN, SONDBERG, WIMBISH & STONE, P.A.
Annapolis, Maryland
March 22, 2007

Note: The accompanying notes are an integral part of these financial statements.

STATEMENTS OF FINANCIAL POSITION
December 31, 2006 and 2005

ASSETS

	2006	2005
CURRENT ASSETS		
Cash and cash equivalents	$ 73,618	$ 71,736
Accounts receivable	17,352	11,447
Due from Foundation	--	2,521
Unconditional promises to give	3,668	--
Prepaid expenses	44,390	47,105
Total current assets	139,028	132,809
PROPERTY AND EQUIPMENT		
Net of accumulated depreciation	2,753	4,803
OTHER ASSETS, net of accumulated amortization		
Unconditional promises to give, net of discount to present value	6,842	--
Trademarks, net of accumulated amortization	10,888	12,454
Total other assets	17,730	12,454
Total assets	$ 159,511	$ 150,066

LIABILITIES AND NET ASSETS

	2006	2005
CURRENT LIABILITIES		
Accounts payable and accrued expenses	$ 6,006	$ 13,514
Due to Foundation	860	--
Settlement payable	--	18,000
Note payable	--	11,137
Deferred revenue	220,060	213,325
Total current liabilities	226,926	255,976
LONG-TERM LIABILITIES		
Note payable	--	5,823
Total long-term liabilities	--	5,823
Total liabilities	226,926	261,799
NET ASSETS		
Unrestricted	(98,652)	(142,970)
Unrestricted – board designated	31,237	31,237
Total net assets	(67,415)	(111,733)
Total liabilities and net assets	$ 159,511	$ 150,066

STATEMENTS OF ACTIVITIES
Years Ended December 31, 2006 and 2005

	2005	2005
REVENUES, GAINS AND OTHER SUPPORT		
Certification fees	$ 333,172	$ 333,239
Publications	67,204	65,146
Contributions	42,007	47,135
Meetings	34,550	47,926
Environmental engineer	11,616	9,905
Other income	7,549	1,916
Forgiveness of debt	7,355	--
Kappe lecture	5,950	9,350
Total revenues, gains and other support	510,403	514,617
EXPENSES		
Program service expenses:		
Memberships	38,787	37,278
Environmental engineer	22,641	32,047
Publications	20,715	18,684
Public education	10,854	15,677
Certificate/membership	9,715	15,275
Meetings and seminars	7,982	26,406
Kappe lecture	6,585	4,534
Committee expense	1,589	1,588
Total program service expenses	118,341	151,489
Management and general expenses:		
Staff salaries, fringe benefits and contract employment	224,956	216,586
Office expense	90,251	87,528
Officer and trustees expenses	12,800	3,419
Legal, accounting and miscellaneous fees	10,976	17,030
Insurance	4,235	3,601
Depreciation and amortization	3,914	4,701
Awards	612	198
Interest	--	1,361
Total management and general expenses	347,744	334,424
Total expenses	466,085	485,913
Change in net assets	44,318	28,704
NET ASSETS AT BEGINNING OF YEAR	(11,733)	(140,437)
NET ASSETS AT END OF YEAR	$(67,415)	$(111,733)

NOTES TO FINANCIAL STATEMENTS
December 31, 2006 and 2005

Note 1 — Summary of Significant Accounting Policies

Nature and Organization
American Academy of Environmental Engineers (AAEE) was founded in 1955 to improve the practice of environmental engineering by certifying properly-qualified environmental engineering specialists, accrediting university environmental engineering curricula and by informing the public and environmental engineers through lectures, publications and other venues regarding proper environmental practices.

Income Taxes
The Academy is exempt under Section 501(c)(6) of the Internal Revenue Code from paying federal income tax on any income except unrelated business income. No provision has been made for income taxes as the Academy has no net unrelated business income.

Basis of Accounting
The Academy prepares its financial statements in accordance with accounting principles generally accepted in the United States of America. The basis of accounting involves the application of accrual accounting; consequently, revenues and gains are recognized when earned, and expenses and losses are recognized when incurred.

Revenue Recognition
Certification fees and certain other revenues are recorded as deferred revenue upon receipt and are recognized in the period to which the fees relate.

Contributions received are recorded as unrestricted, temporarily restricted, or permanently restricted support, depending on the existence and/or nature of any donor-imposed restriction. Support that is restricted by the donor is reported as an increase in unrestricted net assets if the restriction expires in the reporting period

2006 FINANCIAL STATEMENT

in which the support is recognized. All other donor-restricted support is reported as an increase in temporarily or permanently restricted net assets, depending on the nature of the restriction. When a restriction expires (that is, when a stipulated time restriction ends or a purpose restriction is accomplished), temporarily restricted net assets are reclassified as unrestricted net assets and reported in the statement of activities as net assets released from restrictions. Unexpended grant awards are classified as refundable advances until expended for the purpose of the grants since they are considered conditional promises to give.

Use of Estimates

The preparation of financial statements in conformity with accounting principles generally accepted in the United States of America requires management to make estimates and assumptions that affect the reported amounts of assets and liabilities and disclosure of contingencies at the statement of financial position date and the reported amounts of revenues and expenses during the reporting period. Actual results could differ from those estimates.

Cash and Cash Equivalents

For purposes of the statement of cash flows, cash and cash equivalents represent deposits in checking and savings accounts.

Accounts Receivable

Accounts receivable consists of amounts due for certification fees, royalties and reimbursements at the end of the year. The Academy considers all accounts receivable to be fully collectible. Accordingly, an allowance for doubtful accounts has been established.

Promises to Give

Contributions are recognized when the donor makes a pledge to give to the Academy that is, in substance, unconditional. Contributions that are restricted by the donor are reported as increases in

STATEMENTS OF CASH FLOWS
Years Ended December 31, 2006 and 2005

	2006	2005
CASH FLOWS FROM OPERATING ACTIVITIES:		
Change in net assets	$ 44,318	$ 28,704
Adjustments to reconcile change in net assets to net cash provided by operating activities:		
Depreciation and amortization	3,914	4,701
Forgiveness of debt	(7,355)	---
(Increase) decrease in operating assets:		
Accounts receivable	(5,903)	3,421
Due from (to) Foundation	3,381	(2,521)
Unconditional promises to give	(10,510)	--
Prepaid expenses	2,715	(2,933)
Increase (decrease) in operating liabilities:		
Accounts payable and accrued expenses	(7,508)	1,402
Settlement payable	(18,000)	(18,000)
Deferred revenue	6,735	2,583
Net cash provided by operating activities	11,787	17,357
CASH FLOWS FROM INVESTING ACTIVITIES:		
Acquisition of property, equipment and trademarks	(300)	(1,066)
CASH FLOWS FROM FINANCING ACTIVITIES:		
Principal payments on notes	(9,605)	(10,490)
Net change in cash	1,882	5,801
Cash and cash equivalents at beginning of year	71,736	65,935
Cash and cash equivalents at end of the year	$ 73,618	$ 71,736
SUPPLEMENTAL CASH FLOW INFORMATION:		
Cash paid during the year for interest	$ --	$ 1,361

unrestricted net assets if the restrictions expire in the fiscal in which the contributions are recognized. All other donor-restricted contributions are reported as increase in temporarily or permanently restricted net assets depending on the nature of the restrictions. When a restriction expires, temporarily restricted net assets are reclassified to unrestricted net assets.

Property and Equipment

Property and equipment acquisitions in excess of $500 are capitilized and recorded at cost less accumulated depreciation and amortization. When assets are retired or otherwise disposed of, the cost and related depreciation are removed from the accounts, and any resulting gain or loss is reflected in income for the period. The cost of maintenance and repairs is charged to current income as incurred; where as significant renewals and betterments are capitalized. Depreciation and amortization of property and equipment are provided on a straight-line basis. Leasehold improvements are amortized over their estimated useful lives or the life of the lease, whichever is shorter. Furniture and equipment are depreciated over three to ten years.

Program Service Expense

Program service expense represents the direct cost of performing programs. Direct costs do not include salaries and related expenses. Management and general costs have not been allocated to such programs.

Note 2 — Concentration of Cash Balances

At various times during the year, the Academy maintained cash-in-bank balances in excess of the federally insured limit of $100,000.

Note 3 — Unconditional Promises to Give

Unconditional promises to give are as follows at December 31, 2006:

Receivables in less than one year	$ 3,668
Receivables in two years	$ 3,668
Receivables in three years	$ 3,668
Total unconditional promises to give	11,000
Less: discounts to net present value	(490)
	$10,510

Unconditional promises to give are reflected at present value of estimated future cash flows using a discount rate of 4.73%, depending on the date of the original pledge.

Note 4 — Property and Equipment

Property and equipment are summarized below for the years ending December 31:

	2006	2005
Furniture and equipment	$ 207,548	$ 207,248
Leasehold improvements	6,951	6,951
	214,499	214,199
Less accumulated depreciation	(211,746)	(206,396)
Net property and equipment	$ 2,753	$ 4,803

Depreciation expense for the years ended December 31, 2006 and 2005 was $2,350 and $3,141, respectively.

Note 5 — Other Assets

Trademark and organization costs incurred by the Academy are amortized over fifteen years. Amortization expense for the years ended December 31, 2006 and 2005 were $1,564 and $1,560, respectively.

Note 6 — Lease Commitment

The Academy leases office space under a noncancellable operating lease which expires on July 31, 2008.

Future minimum lease payments required under the lease are as follows:

2007	46,548
2008	27,467
	$74,015

Rent expense for the years ended December 31, 2006 and 2005 amounted to $48,766 and $47,588, respectively.

Note 7 — Settlement Payable

In October 2001, the Academy entered into a settlement agreement with a former employee in a wrongful termination lawsuit. The Academy has agreed to pay a total sum of $108,000 in consideration for the release of all claims known or unknown by the plaintiff against the Academy. The Academy shall pay the settled amount in a total of six annual installments of $18,000 to the defendant's counsel. The first installment payment was made in October 2001. The remaining 5 installments are due by February 15 of each year. The balance of the settlement payable as of December 31, 2006 and 2005 was $-0- and $18,000, respectively

Note 8 — Note Payable

In June 2002, the Academy obtained a note that is payable to a law firm in the amount of $51,084. The note was obtained to pay legal fees incurred in 2001 defending a lawsuit (See Note 7). Monthly installments of $988 including interest at 6% are to repaid over 60 months. During the year ending December 31, 2006, the Academy paid $9,605 towards the outstanding principal and the remaining $7,355 principal was forgiven. The balance of the note payable as of December 31, 2006 and 2005 was $-0- and $16,960, respectively.

Note 9 — Employee Benefit Plan

The Academy established a 401(k) Retirement Plan in 1997 for all employees meeting certain eligibility requirements. Employees may contribute up to 15%

❖ Continued on 20 ❖

continued from page 17

of their eligible compensation to the plan, subject to the limits to Section 401(k) of the Internal Revenue Code. The Academy does not match employee contributions.

Note 10 — Related Party Transactions

The balance due (to) from the American Academy of Enviromental Engineers Foundation to the Academy amounted to $(860) and $2,251, for the years ended December 31, 2006 and 2005, respectively.

Note 11 — Unrestricted Net Assets — Board Designated

It is the policy of the Board of Trustees of the Academy to review its plans for future projects from time to time and to designate appropriate sums to assure adequate financing of such projects.

Snow Fund – represents a $10,000 unrestricted contribution for which the Board of Trustees designated for some future use. The Board directed that the $10,000 principal remain intact and that the interest can only be used for purposes designated by the Board. Total designated funds as of December 31, 2006 and 2005 amounted to $14,528. Total accumulated interests as of December 31, 2006 and 2005 amounted to $4,528. The Academy cashed in the Certificate of Deposit for operating purposes during the year ended December 31, 2000 and intend to reestablish the certificate of deposit when funds are available.

Kappe Fund – represents a $10,000 bequest received from the Estate of Stanley E. Kappe during 1985. This unrestricted bequest is used for the purpose of recognizing the contributions of Stanley E. Kappe to the environmental engineering profession. The Board has designated the fund as a Quasi-Endowment. Hence, the principal portion of this fund is to remain intact and the interest can be spent on funding the Kappe Lecture Series. The Board has also designated additional funds and any annual contributions to the Kappe Lecture to be used to fund the Kappe Lecture Series. Total designated funds as of December 31, 2006 and 2005 amounted to $16,709. Total accumulated interest as of December 31, 2006 and 2005 amounted to $3,694. The Academy cashed in the certificate of deposit for operating purposes during the year ended December 31, 2001 and intends to reestablish the certificate of deposit when funds are available.

Note 11 — Going Concern

These statements are presented on the basis that the Academy is a going concern. Going concern contemplates the realization of assets and the satisfaction of liabilities in the normal course of business over a reasonable length of time. The accompanying financial statements show a current year accumulated deficit in unrestricted net assets of $67,415.

The Academy has developed a plan to reduce expenses and increase revenues. The Academy continues to implement the plan. Management has projected cash flows for one year.

The Academy's continued existence depends on the success of cost reductions and development new sources of revenue.

Volume 3, Summer 2007

Environmental Engineer: Applied Research and Practice

APPLIED RESEARCH AND PRACTICE SECTION

Useful Peer Reviewed Papers Emphasizing Technical Real-World Detail

The Academy is pleased to launch a new section of *Environmental Engineer,* focused on applied research and practice in environmental engineering. The Academy Publications Committee recognized the need for a peer reviewed publication focused on practical research and useful case studies related to environmental engineering. The Academy Board concurred, an editorial board was formed and papers were solicited.

Many archival engineering journals emphasize fundamental research and view reports on successful engineering projects as inappropriate for peer reviewed publication. On the contrary, the Applied Research and Practice Section of *Environmental Engineer* encourages publication of useful reports and applied research with an emphasis on technical, real-world detail. Quality is ensured by peer review and by an Editorial Board of experienced practitioners and educators.

It should be pointed out that the Academy is not alone in recognition of the need for a more practice-oriented publication related to environmental engineering. The International Water Association recently launched a new online journal titled *Water Practice & Technology*, and the Water Environment Federation plans to start a new journal titled *Water Practice.* We intend that *Environmental Engineer: Applied Research and Practice* focus will transcend water to include multi-media and professional issues as well.

The Editorial Board encourages submission of papers focused on practical research and useful case studies related to environmental engineering. Practical "know-how" reports, interesting designs, and evaluations of engineering processes and systems are examples of appropriate topics. Manuscripts should follow the general requirements of the ASCE authors guide (http://www.pubs.asce.org/authors/index.html#1) and should be submitted electronically in WORD format to: C. Robert Baillod, Editor, *Environmental Engineer: Applied Research and Practice*, baillod@mtu.edu. The Editorial Board strives for prompt review and publication.

Instructions to Contributors

PURPOSE AND SCOPE

Environmental Engineer: Applied Research and Practice, is a peer-reviewed journal focused on practical research and useful case studies related to the multi-disciplinary field of environmental engineering. The journal strives to publish useful papers emphasizing technical, real-world detail. Practical reports, interesting designs and evaluations of engineering processes and systems are examples of appropriate topics. Papers relating to all environmental engineering specialties will be considered.

MANUSCRIPT REQUIREMENTS:

Manuscripts should follow the general requirements of the ASCE authors' guide (http://www.pubs.asce.org/authors/index.html#1) and should be submitted electronically in WORD format to the Editor and Assistant Editor.

C. Robert Baillod, Ph.D., P.E., BCEE
Editor e-mail: baillod@mtu.edu
Yolanda Moulden
Assistant Editor email: YMoulden@aaee.net

For questions or hard copy submission, please contact:
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AAEE
130 Holiday Court, Suite 100
Annapolis, MD 21401
ATTN: Yolanda Moulden
(410) 266-3311
(410) 266-7653 (Fax)

REVIEW PROCESS

All papers submitted to the journal are subject to critical peer review by three referees, who have special expertise in a particular subject. The Editor will have final authority over a paper's suitability for publication.

CATEGORIES

Papers may be submitted in the following areas:

Applied Research

Original work presented with careful attention to objectives, experimental design, objective data analysis, and reference to the literature. Practical implications should be discussed.

Review

Broad coverage of an environmental engineering application or a related practice with critical summary of other investigators' or practitioners' work.

Practical Notes

Novel methods that the author(s) have found to be sufficiently successful and worth recommending.

Case Studies

Recently completed projects or studies in progress that emphasize novel approaches or significant results.

Design/Operation

Conceptual or physical design or operation of engineering systems based on new models or techniques.

Management

Papers describing novel approaches to problems in environmental management, or to the global, sustainability or business asects of environmental engineering.

ABSTRACT

An abstract of up to 200 words should be provided, including a statement of the problem, method of study, results, and conclusions. References, tables, and figures should not be cited in the abstract. Up to six key words or terms should be included for use by referencing sources.

PHOTOGRAPHIC CONSENTS

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NOVEL METHOD FOR ASSESSING SALINITY TOLERANCE OF MARINE ORGANISMS

Nikolay S. Voutchkov, P.E., BCEE

ABSTRACT

Seawater desalination plants produce concentrate (brine) which is usually 1.5 to 2 times higher than the concentration of total dissolved solids (TDS or salinity) of the ambient seawater. When returned to the ocean without dilution, the concentrate may have negative impact on the aquatic environment in the area of the discharge. This impact is very site-specific and depends to a great extent on the salinity tolerance of the specific marine organisms inhabiting the water column and benthic environment influenced by the discharge. The existing US EPA whole effluent toxicity (WET) tests are indicative of the level of salinity which causes mortality of pre-selected test organisms, which may or may not inhabit the discharge area. This work presents a novel method that allows establishing the site-specific maximum level of salinity concentration (salinity tolerance threshold) at which marine organisms not only survive, but can also grow and reproduce normally. The described method was used successfully for the permitting of the concentrate ocean discharge of two large seawater desalination projects in California – the 189,000 m^3/day (50 MGD) Carlsbad and Huntington Beach desalination plants.

INTRODUCTION

Environmentally safe disposal of the concentrate produced at seawater desalination plants is one of the key factors determining the viability, size and costs of a given project. The maximum total dissolved solids (TDS) concentration that can be tolerated by the marine organisms living in the desalination plant outfall area is defined as a salinity tolerance threshold and depends on the type of the aquatic organisms inhabiting the area of the discharge and the period of time these organisms are exposed to the elevated salinity (Mickley, 2006). These conditions are very site-specific for the area of each desalination outfall and therefore, a general rule of thumb for determining the salinity tolerance threshold is very difficult to develop.

A new method to identify the salinity tolerance of the aquatic life inhabiting the area of a desalination plant discharge was developed at the Carlsbad seawater desalination demonstration plant in California. This method includes the following four key steps:

1. Determination of the Test Salinity Range;
2. Identification of Site-Specific Test Species Inhabiting the Discharge Area;
3. Biometrics Test at Average Discharge Salinity;
4. Salinity Tolerance Test At Varying Concentrate Dilution Levels.

DETERMINING TEST SALINITY RANGE

The first step of the salinity tolerance evaluation (STE) method is to define the minimum and maximum TDS concentrations that are projected to occur in the area of the discharge after the start up of plant operations. This salinity range should be established taking under consideration the effect of mixing and associated dilution in the area of the discharge as a result of the site-specific natural hydrodynamic forces in the ocean (currents, winds, tidal movements, temperature differences, etc.) as well as the mixing energy introduced with the desalination plant discharge diffuser system. If the desalination plant concentrate is diluted with other discharge (i.e., cooling water from power plant or wastewater treatment plant effluent) prior to the exit from the outfall into the ocean, this additional dilution should also be accounted for when establishing the salinity range for which the salinity tolerance of the aquatic species is assessed. Because of the complexity of the various factors that impact the mixing and dilution of desalination plant concentrate with the ambient ocean water, especially for large projects (i.e. projects with discharge volume of 1 MGD or higher), the actual salinity range that would occur in the area of the discharge should be determined based on hydrodynamic modeling (Jenkins and Wasyl, 2001; Einav and Lokiec, 2003).

As a minimum, the salinity test concentrations should range from the TDS concentration at the middle of the water column and the middle of the zone of initial dilution (ZID) to the maximum seabed salinity concentration at the edge of the ZID (Jenkins and Wasyl, 2001). The ZID is defined as the area of the ocean within 1,000 ft from the point of the desalination plant discharge.

IDENTIFYING TEST SPECIES

The purpose of the second step of the STE method is to identify the most sensitive, site-specific species that would be indicative of the salinity tolerance of the aquatic flora and fauna in the area of the desalination plant discharge. These species are used for the Biometrics and Salinity Tolerance Tests. At least three species should be selected for the tests: one representative for the fish population in the area, one for the invertebrate population and one for macro-algal population (i.e., kelp, red alga, etc), if such species are present and occur in significant numbers (California State Water Board, 1996; Chapman et al, 1995; Weber et al, 1998). The selection of the specific test species should be completed by an expert marine biologist that is very familiar with the site-specific aquatic flora and fauna in the area of the desalination plant discharge. The test species should be selected based on: (1) presence and abundance in the area; (2) environmental sensitivity (i.e., endangered/protected marine species are first priority); (3) sensitivity to salinity in the range projected to occur in the discharge; (4) significance in terms of commercial and recreational harvesting/fishing.

THE BIOMETRICS TEST

The purpose of the Biometrics Test is to track how well the indicative test species will handle a long-term steady-state exposure to the elevated average discharge salinity that will occur in the middle of the zone of initial dilution after the desalination plant is in operation (Le Page, 2004). The Biometrics Test should be completed in a large marine aquarium (test tank) in which the desalination plant concentrate is blended with ambient seawater to obtain salinity not to be exceeded in the middle of the ZID in the ocean for at least 95 % of the time. This salinity level should be maintained in the aquarium for the duration of the test. In addition, a second aquarium (control tank) of the same size and number and type of test marine organisms should be employed, with the main difference that this tank should be filled up with ambient seawater collected from the area of the discharge. The control tank should be operated in parallel with the test tank and observations from this tank are used as a base for comparison and statistical analysis.

Once the salinity in the aquariums is set to target levels, they should be populated with the selected test species and key biometric parameters (appearance; willingness to feed; activity; weight gain/loss, and gonad production) of these species should be monitored frequently (minimum every two days) by an expert marine biologist over a prolonged period of time (minimum of three months, preferably five or more months). Percent weight gain/loss and fertilization for one or more of the test and control organisms should be measured as well. At the end of the test, the qualitative and quantitative biometric parameters of the marine species in the test and control tanks should be compared to identify if the species exhibit statistically significant differences – especially in terms of weight gain/loss and fertilization capabilities.

THE SALINITY TOLERANCE TEST

The main purpose of the salinity tolerance test is to establish if the selected test species will survive the extreme salinity conditions that may occur within the ZID and on the edge of the ZID, and if these organisms will be able to retain their capacity to reproduce after exposure to these conditions for a length of time that is expected to occur in full scale operations under worst-case scenario. The test species should be exposed to several blends of concentrate and ambient seawater that can occur within the range of the discharge salinities. The low end of the range should be the average salinity in the ZID (mid-depth) and the high end should be the maximum salinity above the seabed at the boundary of the ZID (i.e., 1,000 ft from the point of the discharge). In general, discharge salinity is expected to decrease with distance from the point of concentrate discharge and to increase with depth (Jenkins and Waysil, 2001). The rate of decrease of discharge salinity from the point of discharge depends on the hydrodynamic conditions in the vicinity of the discharge.

Similar to the Biometrics Test, this experiment includes two sets of aquariums for each salinity concentration – a series of test tanks, one for each test salinity level, and a control tank. The duration of the Salinity Tolerance Test should be determined by the length of occurrence of the worst-case discharge salinity scenario. This duration should be established based on the results from the hydrodynamic modeling of the desalination plant discharge. Usually, extreme salinity discharge conditions are not expected to continue for more than two weeks. However, if this is likely in specific circumstances, than the length of the study should be extended accordingly. Starting from the low end of the salinity concentration, individual test tanks should be set for salinity increments of 1,000 mg/L to several thousand mg/L to cover the range, until the maximum test salinity concentration is reached.

APPLICATION OF THE SALINITY TOLERANCE EVALUATION PROCEDURE TO THE CARLSBAD DESALINATION PROJECT

The STE procedure described above was applied to assess the discharge impact of the 50 MGD Carlsbad seawater desalination project, located in Southern California. This project includes direct connection of the desalination plant intake and discharge facilities to the discharge outfall of an adjacent coastal power generation plant using seawater for once-through cooling (see Figure 1). The power plant has a total of five power generators and depending on the number of units in operation pumps between 200 MGD and 820 MGD of cooling water through the condensers. The warm cooling water from all condensers is directed to a common discharge tunnel and lagoon leading to the ocean. The full-scale desalination facility, is planned to tap into this discharge tunnel for both desalination plant feed water and for discharging high-salinity concentrate downstream of the intake area.

Water collected from one end of the power plant discharge canal will be conveyed to the desalination plant to produce fresh water, and the concentrate from the desalination plant will be returned into the same discharge canal, approximately 800 feet downstream from the point of intake. The desalination plant concentrate, containing approximately two times the salinity of the source seawater (68 ppt vs. 33.5 ppt) will be blended with the remaining cooling water discharge of the power plant and conveyed to the ocean for disposal.

The salinity range of the mixed discharge from the Carlsbad seawater desalination plant and the power plant will be between 35 parts per thousand, (ppt) to 40 ppt. The average salinity in the middle of the ZID is projected to be 36 ppt. Therefore, the Biometrics Test was completed for this salinity, while the test range for the Salinity Tolerance Test covered 37 ppt to 40 ppt in 1 ppt increments. Both tests were

FIGURE 1 Desalination Plant

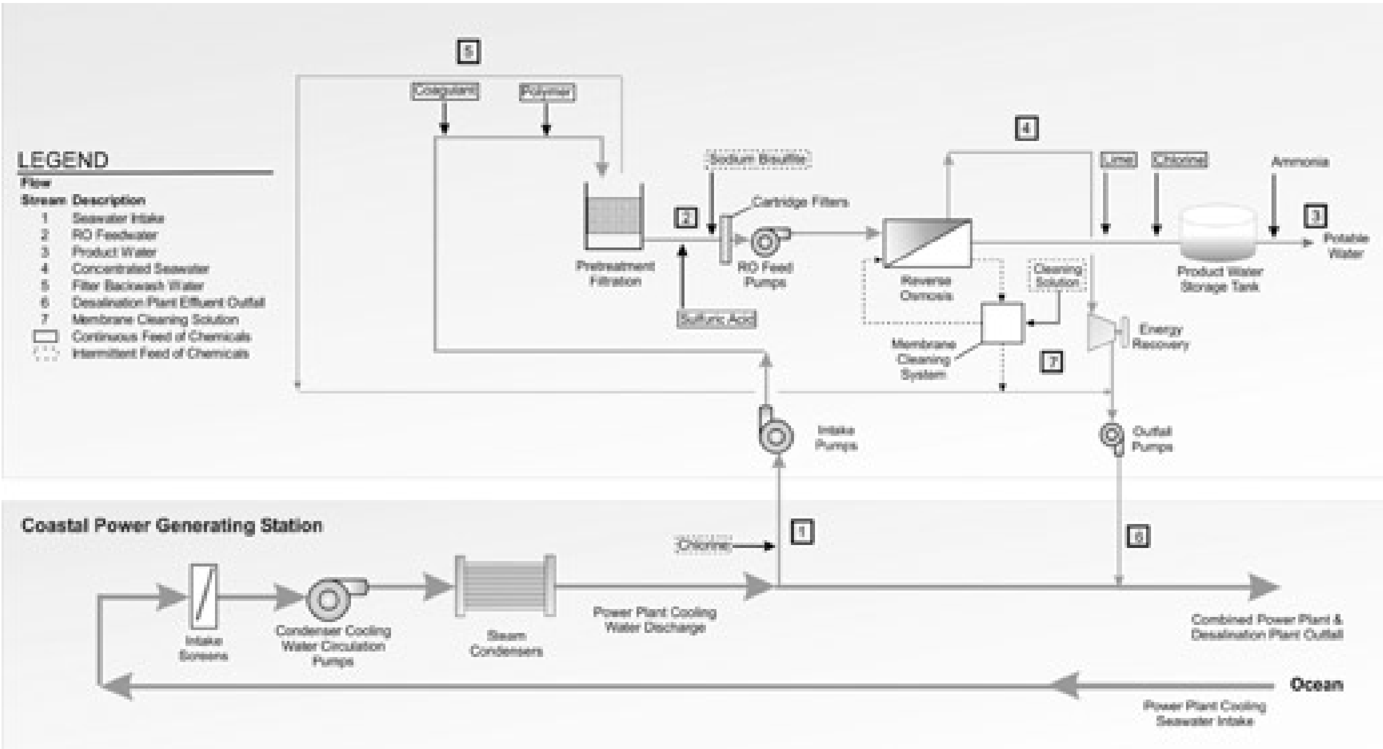

TABLE 1 Marine Species Used for the Carlsbad Biometrics Test

	Scientific Name	Common Name	Number of Individuals
1	*Paralichthys californicus*	California halibut	5 juveniles
2	*Paralabrax clathratus*	Kelp bass	3 juveniles
3	*Paralabrax nebulifer*	Barred sand bass	3 juveniles
4	*Hypsoblennius gentilis*	Bay blenny	5
5	*Strongylocentrotus franciscanus*	Red sea urchin	4
6	*Strongylocentrotus purpuratus*	Purple sea urchin	14
7	*Pisaster ochraceus*	Ochre sea star	3
8	*Asterina miniata*	Bat star	3
9	*Parastichopus californicus*	Sea cucumber	2
10	*Cancer productus*	Red rock crab	2
11	*Crassadoma gigantea*	Giant rock scallop	3
12	*Haliotis fulgens*	Green abalone	3
13	*Megathura crenulata*	Giant keyhole limpet	3
14	*Lithopoma undosum*	Wavy turban snail	3
15	*Cypraea spadicea*	Chestnut cowrie	3
16	*Phragmatopoma californica*	Sand castle worm	1 colony
17	*Anthropleura elegantissima*	Aggregating anemone	4
18	*Muricea fruticosa*	Brown gorgonian	1 colony
19	*Haliotis rufescens*	Red Abalone	5
20	*Dendraster excentricus*	Sand Dollar	5

executed by Dr. Steven Le Page of M-REP Consulting (Le Page, 2004) who is very familiar with the local flora and fauna in the area of the future desalination plant discharge.

A list of the 18 marine species selected for the Biometrics Test for the Carlsbad Project is presented in Table 1. The Salinity Tolerance Test was completed using three local species which are known to have highest susceptibility to stress caused by elevated salinity (Le Page, 2004; Graham, 2004): (1) the Purple sea urchin (*Stronglyocentroutus purpuratus*), Figure 2; (2) the Sand dollar (*Dendraster excentricus*), Figure 3; and (3) the Red Abalone (*Haliotis rufescens*), Figure 4.

The Biometrics and Salinity Tolerance Tests were completed in 110-gallon marine aquariums (Figure 5).

The Biometrics Test was continued for a period of 5.5 months. The results of this test are summarized in Table 2, and indicate that all organisms remained healthy throughout the test period. No mortality was encountered and all species showed normal activity and feeding behavior. The appearance of the individuals remained good with no changes in coloration or development of marks or lesions.

FIGURE 2 Red Sea Urchin

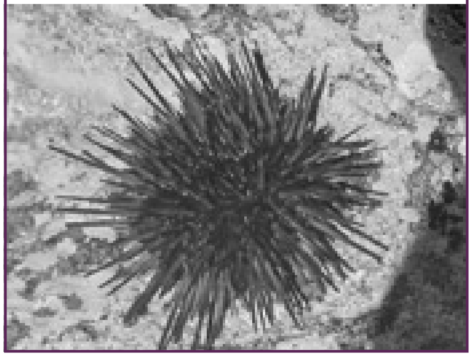

FIGURE 3 Sand Dollar

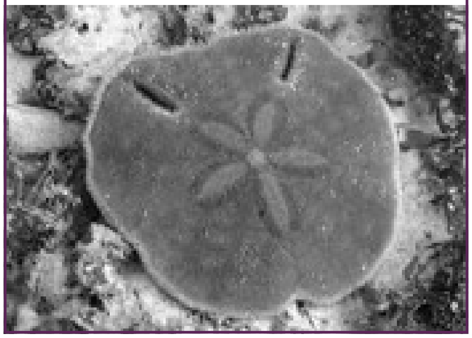

FIGURE 4 Red Abalone

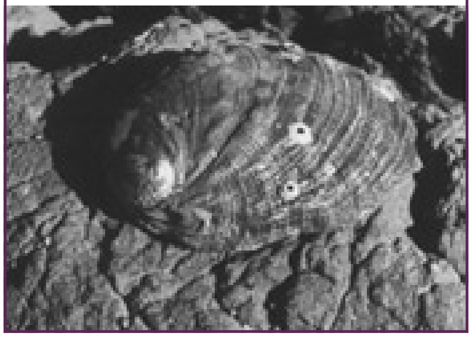

FIGURE 5 Carlsbad Biometrics Test Tank

TABLE 2 Overall Condition and Average Weight Gain of Biometrics Test Species

Scientific Name	Common Name	Avg. % wt. change (grams)	% wt. change (Control group)	Sig.	Appearance and Feeding
Paralichthys californicus	California halibut	91.3	96.9	n/s	Strong
Paralabrax clathratus	Kelp bass	114.3	104.8	n/s	Strong
Paralabrax nebulifer	Barred sand bass	106.8	113.5	n/s	Strong
Hypsoblennius gentilis	Bay blenny	120.0	107.1	n/s	Strong
Strongylocentrotus franciscanus	Red sea urchin	2.8	2.4	n/s	Strong
Strongylocentrotus purpuratus	Purple sea urchin	7.9	7.2	n/s	Strong
Pisaster ochraceus	Ochre sea star	3.8	4.6	n/s	Strong
Asterina miniata	Bat star	2.8	3.1	n/s	Strong
Parastichopus californicus	Sea cucumber	-2.2	2.3	n/s	Strong
Haliotis fulgens	Green abalone	9.6	7.7	n/s	Strong
Megathura crenulata	Giant keyhole limpet	5.1	4.7	n/s	Strong
Lithopoma undosum	Wavy turban snail	3.9	2.4	n/s	Strong
Cypraea spadicea	Chestnut cowrie	0.6	1.0	n/s	Strong
Anthropleura elegantissima	Aggregating anemone	115.9	48.9	n/s	Strong
Haliotis rufescens	Red Abalone	9.2	7.8	n/s	Strong
Dendraster excentricus	Sand Dollar	3.5	4.5	n/s	Strong

Note: n/s = not significant and Sig. = Statistical significance

The duration of the Salinity Tolerance Test for the Carlsbad project was 19 days. The results of this test are given in Table 3 and show that both Sand dollars and Red abalones had 100 % survival in all test tanks and in the control tank. One individual of in the Purple sea urchin group died in each of the test tanks and one died in the control tank. Therefore, the adjusted survival rate for the Purple sea urchins was also 100 %. These test results confirm that the marine organisms in the discharge zone would have adequate salinity tolerance to the desalination plant discharge in the entire range of operations of the desalination plant (i.e., up to 40 ppt). All individuals of the three tested species behaved normally during the test, exhibiting active feeding and moving habits.

In summary, the Salinity Tolerance Evaluation Method applied to the Carlsbad seawater desalination project confirms that the elevated salinity in the vicinity of the plant discharge would not have a measurable impact on the marine organisms in this location and these organisms can tolerate the maximum salinity of 40 ppt that could occur in the discharge area under extreme conditions.

Additional acute and chronic toxicity studies completed subsequently for this project using the United States Environmental Protection Agency's standard whole effluent toxicity (WET) test (California State Water Board, 1996) have confirmed the validity of the new STE method. WET testing using Abalone (*Haliotis ruefescens*) showed that the chronic toxicity threshold for these species occurs for TDS concentration of over 40 ppt. An acute toxicity test completed using another standard WET species, the Topsmelt (*Atherinops affinis*), indicates that the salinity in the discharge can reach over 50 ppt on a short-term basis (one day or more) without impacting this otherwise salinity-sensitive species.

The results of the salinity tolerance evaluation completed for the Carlsbad desalination project were well accepted by the state and local regulatory agencies (San Diego and Santa Ana Regional Water Quality Control Boards (RWQCBs) in California) responsible for environmental protection in California. These results were also used for the environmental review and permitting of the 50 MGD Huntington Beach desalination project, which is developed by Poseidon Resources in parallel with the

TABLE 3 Results of the Salinity Tolerance Test			
Species observed	**Salinity (ppt)**	**Mortality**	**Elapsed time to First mortality (Days)**
Red abalones	33.5 (Control Tank)	0	N/A
Red abalones	37	0	N/A
Red abalones	38	0	N/A
Red abalones	39	0	N/A
Red abalones	40	0	N/A
Sand dollars	33.5 (Control Tank)	0	N/A
Sand dollars	37	0	N/A
Sand dollars	38	0	N/A
Sand dollars	39	0	N/A
Sand dollars	40	0	N/A
Purple sea urchins	33.5 (Control Tank)	1	1
Purple sea urchins	37	1	1
Purple sea urchins	38	1	4
Purple sea urchins	39	1	4
Purple sea urchins	40	1	6

N/A – Not Applicable.

Carlsbad project. In August 2006 both projects received permits to discharge their concentrate to ocean (San Diego RWQCB, 2006; Santa Ana RWQCB, 2006). In addition, the innovative STE method described herein was recognized by the American Academy of Environmental Engineers, which recently awarded Poseidon Resources the 2006 Grand Prize for Applied Research for work completed at the Carlsbad desalination demonstration plant, including the STE studies (EE, 2006). In September this project also received the 2006 Global Grand Prize in the "Applied Research" category by the International Water Association – the highest recognition for innovation in the water and wastewater research field worldwide (EE, 2007).

SUMMARY AND CONCLUSIONS

The novel Salinity Tolerance Evaluation (STE) procedure described in this paper facilitates assessment of the impacts of a desalination plant discharge on the marine organisms in the vicinity of the discharge. This procedure has been successfully applied to the environmental assessment of two large seawater desalination projects located in Carlsbad and Huntington Beach in Southern California.

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ENERGY-SAVING BENEFITS OF DENITRIFICATION

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ABSTRACT

Nitrogen removal in wastewater treatment can be achieved by introducing anoxic zones in biological reactors within an activated sludge process, operating at medium or long mean cell retention time (MCRT). Anoxic zones at the head of the process also function as biological selectors and provide benefits in addition to nitrogen removal, including improved stability by avoiding filamentous bulking, enhanced removal of many recalcitrant pollutants and reduced energy consumption due to the oxygen credit and higher oxygen transfer efficiency. Improved oxygen transfer occurs because the readily biodegradable organic compounds are used by the denitrifiers for nitrate reduction. These organic compounds, which are surfactants, would otherwise reduce oxygen transfer efficiency, increasing plant operating costs. We tested 22 treatment plants which included either conventional, nitrifying-only, or nitrifying-denitrifying (NDN) operations. Off-gas tests confirm that oxygen transfer efficiency for NDN operations is higher. Our economic analyses show that NDN operation can have the lowest aeration costs, contrary to long-standing beliefs. The net operating costs can be lower than conventional, short MCRT operation and are always lower than nitrifying-only operation. However, depending on the local plant situation, expansion of aeration volume and/or clarifier area might be necessary, and the operating savings could be offset by debt service on plant expansion.

INTRODUCTION

The Need for Nitrogen Removal

Urban areas in the United States have generally implemented full secondary treatment and in some cases more advanced treatment, depending on the needs of the receiving waters. Typically, plants on the West Coast that discharge to ocean waters are generally designed to remove only carbon and do not remove nutrients. Recently, inland plants have been required to upgrade for biological nutrient removal (BNR). Water reclamation is often the motivation for upgrading, and a greater fraction of the wastewater treatment plant effluents are now being recycled via indirect potable reuse. Nitrogen removal can be a strict requirement for water reclamation, depending on the application. Therefore, treatment plants that are candidates for reclamation are being upgraded to remove nitrogen.

Nitrogen removal can be achieved by modifications to effect nitrification and denitrification (NDN) in existing activated sludge plants, and many existing facilities are currently undergoing upgrades. New designs typically include NDN and may also provide for phosphorus removal. Phosphorus removal is generally not required in California but is required in the Great Lakes basin and is common in the Eastern United States.

Stability and Performance of NDN

The inherent characteristic of NDN processes is operation at high mean cell retention time (MCRT), which is required to maintain the slower growing nitrifiers. Typically the range of MCRT for NDN plants is 4.5-30 days. Plants in warmer regions benefit from higher microbial reaction rates, and can operate in NDN mode at lower MCRT values. Plants operating at low loading rates (i.e., high MCRT or low food-to-microorganism ratio [F/M]) are generally better in removing recalcitrant organic compounds and may produce lower effluent soluble COD or organic carbon (Babcock et al, 2001). Here-to-fore, the benefits of operation at high MCRT conditions have not been great enough to convince plant managers to operate at these conditions. The availability of biological selectors to increase process stability and the improvement in oxygen transfer rates associated with the higher MCRT values (Fisher and Boyle, 1999) are now well known and provide new incentive to operate at high MCRT conditions.

Parker et al. (2003) surveyed 21 plants with anoxic and anaerobic selectors, and reported that all plants showed improvement after selector installation. Among the plants with anoxic selectors, 70% had sludge volume index (SVI) lower than 200 ml/g. Plants using anaerobic selectors were even better and more than 90% of the plants had SVIs less than 150 ml/g. Martins et al (2004) reported similar results and concluded that better operation is achieved if there is a first anaerobic stage. The benefit of selectors is the reduction of filamentous organisms (Harper and Jenkins, 2003), which improves SVI and reduces the probability of sludge bulking and rising sludge blankets in secondary clarifiers (Jang and Schuler, 2007). The activity of phosphorus accumulating organisms (PAO) was reported to increase even when operating a strictly anoxic selector, with PAO improving the floc structure and biomass density (Tampus et al, 2004).

In addition to these advantages, there

is growing evidence that processes operating under high MCRT conditions are more efficient in removing anthropogenic compounds, such as pharmaceuticals (Soliman et al., 2006; Goebel et al, 2007). Andersen et al (2003) reported removals up to 90% for the endocrine disruptor 17a-ethinylestradiol (EE3) after a wastewater treatment plant was retrofit to remove nutrients at MCRT of 11-13 days. Operation at high MCRT conditions in order to enhance removal of trace organics will become more important as wastewater water reclamation becomes more widely practiced.

Advantageous Economics of Denitrification

Aeration is the most energy-intensive unit operation in wastewater treatment plants, amounting to 45-75% of plant operating costs (Reardon, 1995). Treatment plants operating with NDN typically show improved oxygen transfer efficiency (OTE), with consequent lower energy requirements (Groves et al, 1992; Rosso and Stenstrom, 2005). This improved transfer efficiency results mainly because of higher MCRT operation, which is associated with increased α factors (0.2-0.5 for conventional treatment, 0.4-0.7 for nitrification-only, 0.5-0.75 for NDN), but has not always been recognized by design engineers. An advantage of selectors is the removal or sorption of a fraction of the carbonaceous load, i.e. the readily biodegradable COD (rbCOD). The rbCOD is partially composed of surface active agents or surfactants, which are typically discharged as fatty acids, oils, soaps and detergents. The surfactants, because of their amphiphilic nature, accumulate at the air-water interface of rising bubbles, reducing oxygen transfer efficiency. Removal of the rbCOD can improve oxygen transfer efficiency and can reduce operating costs for aeration (Rosso and Stenstrom, 2006a). The increase in transfer efficiency is in addition to the reduction in oxygen demand due to denitrification.

The economic advantages of NDN are discussed in detail in this paper. We performed mass- and energy- balances over NDN processes, and quantified unit operating costs and credits. We compare conventional treatment, nitrifying-only, and NDN, showing the advantageous economics of NDN. Differences in capital cost, such as the possible need for increased aeration tank volume and clarifier area, are too site-specific to be quantified here. Although the influence of capital cost is not included in our calculations, it is discussed.

BACKGROUND

Oxygen Transfer and Aeration Efficiency

Fine-pore diffusers are now the most commonly used aeration technology in municipal wastewater treatment in the United States. They have higher efficiencies on the basis of energy consumption (standard aeration efficiency [SAE], measured in lb O_2/hp-hr or kg O_2/kWh). Fine-pore diffuser systems strip the fewest volatile organic compounds by virtue of their increased efficiency, which results in lower airflow rates (Hsieh et al., 1993a and b). Fine-pore diffusers also have reduced heat losses for the same reason (Sedory and Stenstrom, 1995; Talati and Stenstrom, 1990).

Two important disadvantages must be taken into consideration when operating fine-pore diffusers: the need for periodic cleaning and the deleterious effect on oxygen transfer efficiency from wastewater contaminants, which is most often quantified by the α factor (ratio of process water to clean water mass transfer coefficients, or K_La_{pw}/K_La_{cw}). The economic implications of fine-pore diffuser ageing have been recently quantified by the authors (Rosso and Stenstrom, 2005). In general, fine-pore diffusers show lower α factors than coarse-bubble diffusers or surface aerators (Stenstrom and Gilbert, 1981; Rosso and Stenstrom, 2006a). Differences in α factors among aeration systems were observed as early as in the 1930s by Kessener and Ribbius (1935), but were generally forgotten until the early 1980s, when fine-pore diffusers became popular again due to increased energy cost. Many plants were initially designed with arbitrarily chosen α factors of 0.8 for all aeration technologies (i.e., fine- vs. coarse-bubbles vs. surface aerators), which resulted in under-designed aeration systems and considerable controversy among competing manufacturers. In our experience we have measured α factors for fine-pore diffusers in the range of 0.2 to 0.7 (with rare exceptions), and in the range of 0.6 to 0.9 coarse bubble diffusers and surface aerators.

The standardized oxygen transfer efficiency in process water (αSOTE) and the α factor are functions of mean cell retention time (MCRT) or sludge age, of the air flow rate (AFR), and of tank geometry (diffuser submergence, number, and unit area), as previously discussed and quantified (Rosso *et al*., 2005). Fine-bubble aeration systems in activated sludge processes operating at low loading rates (i.e., high MCRT or low F/M) are generally associated with higher α factors (Groves et al., 1992).

Measuring Aeration Efficiency with the Off-Gas Technique

First developed by Redmon *et al.* (1983) in conjunction with the U.S. Environmental Protection Agency (EPA)-sponsored American Society of Civil Engineers (ASCE) Oxygen Transfer Standards Committee, the off-gas technique has become the method of choice for process water testing of subsurface aeration systems. Testing protocols are described in detail in ASCE publications (ASCE, 1997). By performing off-gas testing, we can accurately and precisely measure oxygen transfer for diffused aeration systems (coarse-bubble diffusers, fine-pore diffusers, turbines, and jets) at virtually all process conditions. The dissolved oxygen concentration, or the oxygen uptake rate, or the aeration system air flow rate do not interfere with or limit the test procedure. Off-gas measurements over long periods of time have proven useful for plant performance improvement (Libra et al., 2002). Recently, a low-cost automated real-time off-gas analyzer was developed and deployed in municipal treatment plants in Southern California, and its design will be released to the public domain in 2007 (Leu et al., 2007).

Clean water test results are necessary to calculate the effect of process water on oxygen transfer efficiency, i.e. to calculate the α factor. Clean water results can be reported as standard oxygen transfer efficiency (SOTE, %), standard oxygen transfer rate (SOTR, kgO_2/h or lbO_2/h), or standard aeration efficiency (SAE, kgO_2/kW-h or lbO_2/HP-h). Standard conditions are defined in a protocol (ASCE, 1991) and correspond to 20ºC, mean atmospheric pressure, zero dissolved oxygen, and zero effect of salinity or other contaminants (e.g., α factor = 1.0, β factor = 1.0). Because it is generally not possible or easy to measure α factors, process water transfer efficiencies are generally reported as αSOTE, which includes all adjustments (DO, temperature, barometric pressure, salinity), except the α factor. We also use this approach, which is convenient because the other non-standard conditions are easily measured. The α factor can be calculated from off-gas results when clean water data are available:

$$\alpha = \frac{\alpha(\text{SOTE})}{\text{SOTE}} \tag{1}$$

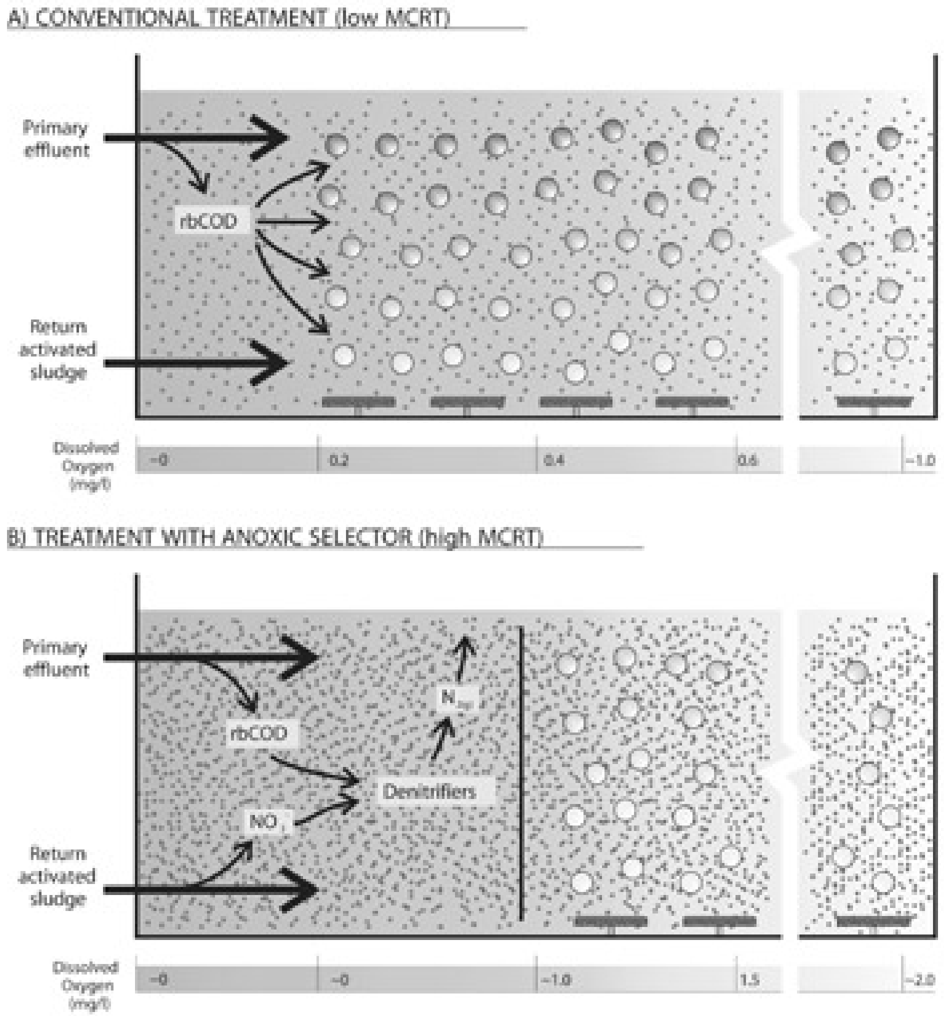
When it is desirable to differentiate the effects of wastewater contaminants and fouling, an αF factor is often used. In this work we use α for new or recently cleaned fine-pore diffusers, and αF for fouled fine-pore diffusers. Since coarse-bubble diffusers do not show significant effects of fouling, α may be used in lieu of αF for coarse-bubble diffusers which have been in operation for long time. When calculating SAE or power consumption, care is necessary because different power measurements may be used. In general, "wire" power is preferable, but requires site-specific information. Wire power is used in this paper.

FIELD OBSERVATIONS

The current database and analyses include data from 113 tests at 22 treatment plants conducted over the last 25 years using the off-gas procedure. Fourteen of the plants were conventional, three plants were operating as nitrifying-only, and five plants were operating in NDN mode. Eighty-four of the tests were for conventional treatment operations, nine tests were for nitrifying-only plants and twenty tests for NDN operation. The MCRT range for conventional plants was 1.2 to 8.5 days. In Southern California, as well as in other warm regions, nitrification can be achieved at the lower MCRTs because wastewater temperatures are typically between 26 and 28°C in the summer and seldom below 20°C during winter. In the current database, the range of MCRTs for nitrification-only was 12 to 21 days and for NDN was 5 to 22 days.

All plants tested were equipped with fine-pore diffusers which included: ceramic discs and domes, membrane discs, tubes and panels, and plastic discs and tubes. Equipment from eleven different manufacturers was included in our dataset. The range of diffuser ages varied from new (less than 1 month of operation) to used (within the first 24 months of operation) to old (greater than 24 months operation). Diffusers that had been cleaned within one month of testing were classified as cleaned. Diffuser cleaning can be achieved by tank-top hosing, mechanical scrubbing, or chemical cleaning (with liquid or gaseous acid). We grouped all cleaning methods together because the effects of different methods, at least within the present dataset, were too small to quantify.

FIGURE 1 Pathway and Fate of Readily Biodegradable COD (Mostly Surfactants) In Conventional Tanks and Anoxic Selectors.



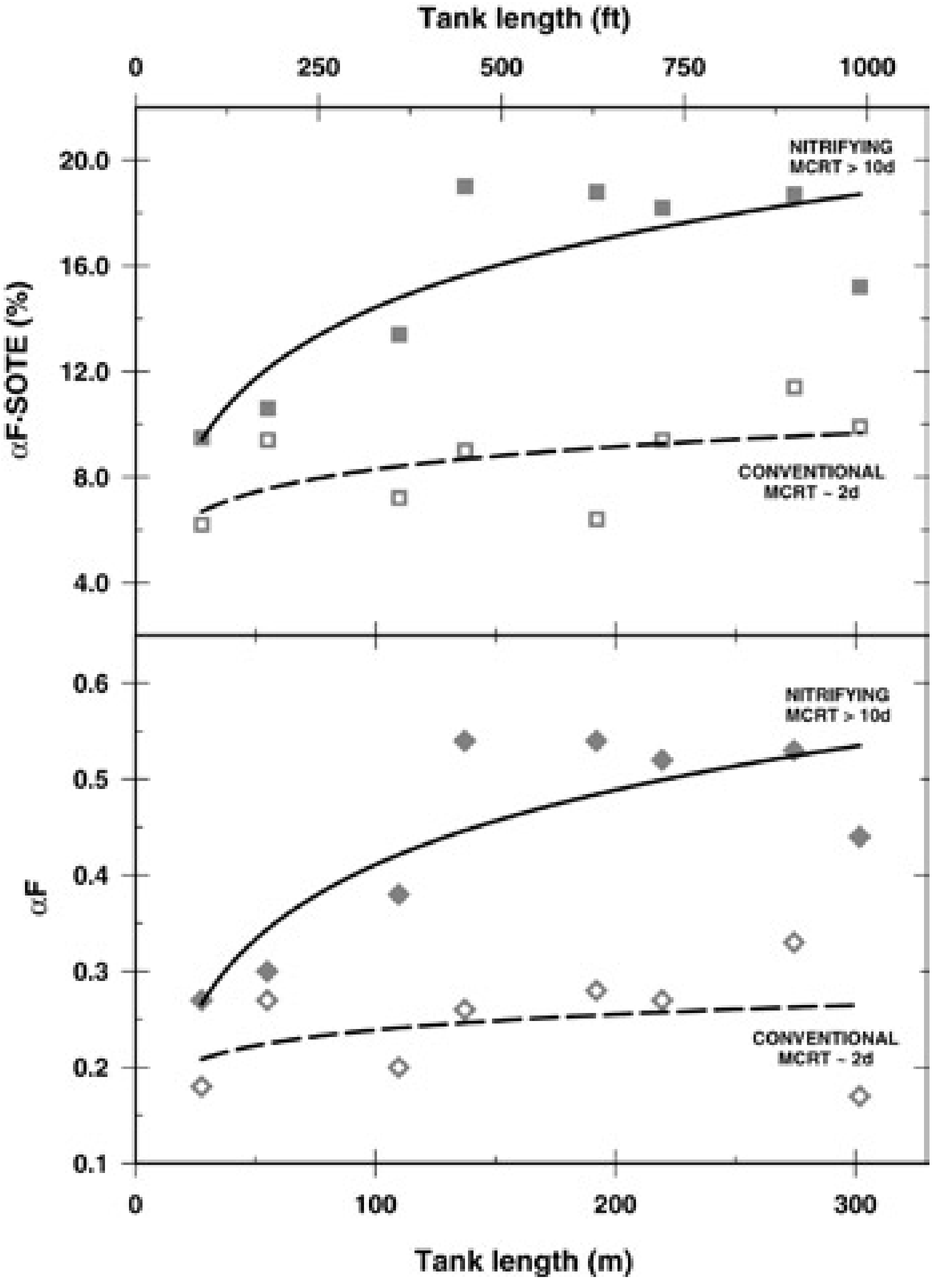
The plants had a range of construction features that may impact process operation. Baffle design, in particular, can impact operation. Baffles with submerged tops were generally effective in separating the anaerobic or anoxic mixing zones without selecting for foam producing organisms and creating nuisance and odor problems with dried spray. Baffles that extended well above the surface were the worst performing and invariably retained foam and had the worst nuisance and odor problems, often requiring manual, periodic scum removal. The ideal baffle design is discussed later and created a small water fall that prevented backflow while ensuring that scum was transported out of the selector zones (Narayanan et al, 2003).

DISCUSSION

Process Considerations

Conventional treatment is typically operated at lower MCRT conditions with lower biomass concentrations and offers less opportunity for dissolved substrate to be sorbed by the biomass. Higher MCRT operations have the advantage of higher biomass concentration. Given the same average MCRT, treatment systems using anaerobic selectors or coupling nitrification and denitrification have the additional advantage of partially removing or sorbing readily biodegradable substrate (rbCOD) in the selector zone. This is beneficial because of decreased overall oxygen requirements (in the case

FIGURE 2 A Tale of Two Side-by-side Tanks Treating the Same Wastewater with Separate Clarifiers.



of anoxic or nitrate-reducing selectors), and increased oxygen transfer efficiency (Eckenfelder and Ford, 1968; Rosso and Stenstrom, 2006a). The expected pathway and fate of rbCOD in conventional tanks and anoxic selectors are illustrated in Figure 1 where dots represent contaminants, and circles are air bubbles. Anoxic selectors have the potential to partially remove rbCOD, which otherwise would accumulate onto fine-bubbles and reduce oxygen transfer. This is the reason for improved efficiency in denitrification plants, when compared to nitrifying-only operating at same MCRT.

Figure 2 illustrates the impact of higher MCRT values on oxygen transfer. These data came from a plant operating two side-by-side tanks with serpentine layout (4 passages of 75 m each), one operating with conventional process (MCRT ~ 3.2 days; 1900 mg_{MLVSS}/l) and the other with nitrification-only (MCRT ~16 days; 2500 mg_{MLSS}/l).For both tanks, aeration was performed with fine-pore ceramic disc diffusers, influent BOD_5 was 180 mg/l, and influent NH_4^+-N was 27.2 mg/l. The tank operated in conventional mode shows consistently lower α factors and αFSOTE throughout the process. By comparing the flow-weighted averages for α and αFSOTE over the entire tanks, the overall improvement of operating at higher MCRT is about a two-fold increase in the aeration efficiency. Note that a two-fold increase in efficiency may not correspond to a 50% reduction in surfactant concentration, as the "faster" surfactants (i.e. lower molecular weight) have much more severe impact on efficiency than the "slower" surfactants (i.e., higher molecular weight). Direct surfactant removal measurements are therefore required, and may not be inferred from the variation in efficiency.

Figure 3 shows the improvement in OTE attained by introducing an anoxic selector in a high MCRT activated sludge process. This is another treatment plant with side-by-side aeration tanks and separate clarifiers with one with conventional layout (MCRT ~ 3.1 d; 1130 mg_{MLSS}/l) and one with NDN (MCRT ~ 13.8 d; 3610 mg_{MLSS}/l). Both tanks were equipped with fine-pore ceramic disc diffusers, BOD_5 influent concentration was 132 mg/l, and NH_4^+ influent concentration was 25.3 mg/l. At the head of the aeration tank, where the greatest oxygen uptake rate occurs, the oxygen transfer rate is most depressed by low α factors. The first 30% of the NDN aeration tank was not aerated and functioned as an anoxic selector. The NDN tank has no α defined in the anoxic zone, but consistently higher values for α along the entire aerated zone. In cases where the process operates at high MCRT, the average α factor will be greater and if there is internal mixed liquor recirculation, the gradient is reduced. Internal recirculation is normally used to improve nitrogen removal, but also distributes load, reducing amount of aeration tapering that is required.

The effect of dissolved contaminants on aeration efficiency is shown in Figure 4. In this figure, a subset of the entire dataset was plotted. Aeration efficiency is reported as standardized aeration efficiency in process water or αFSAE for fine-pore diffusers and αSAE for coarse-bubbles, turbines, jets, and surface aerators (all not prone to fouling). Clean water test results as well as results from process water testing are plotted. The horizontal axis is air flow per diffuser. At low air flow, fine bubbles are created while at high flow coarse bubbles occur. Higher

FIGURE 3 Effect of Tank Length and Anoxic Selectors on α for Side-By-Side Treating the Same Wastewater with Conventional and NDN Operations.

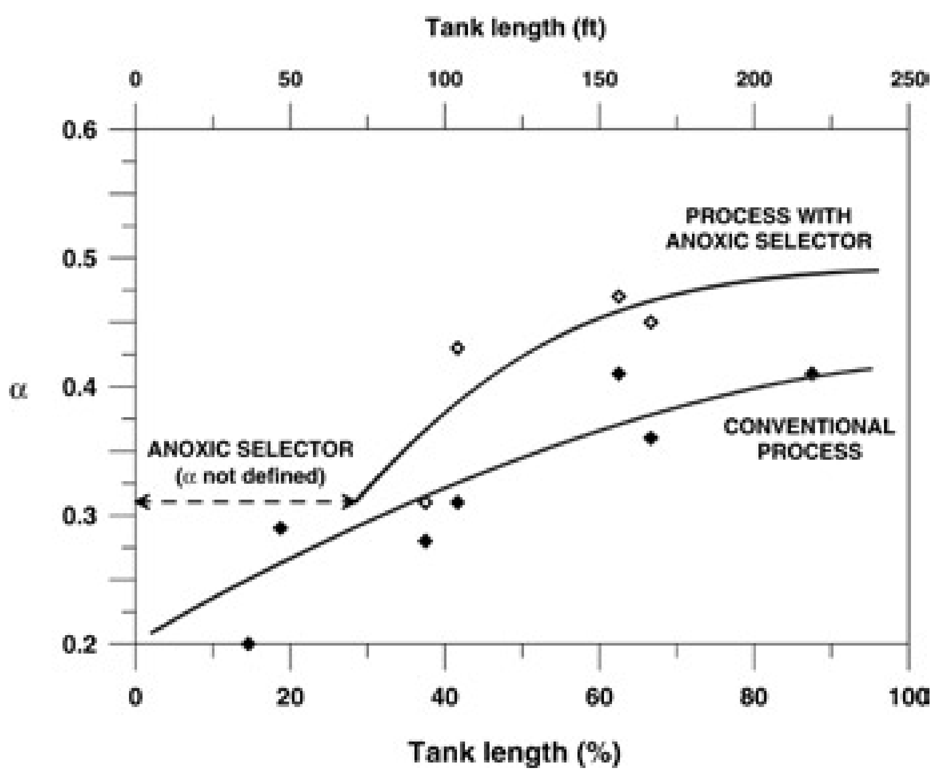
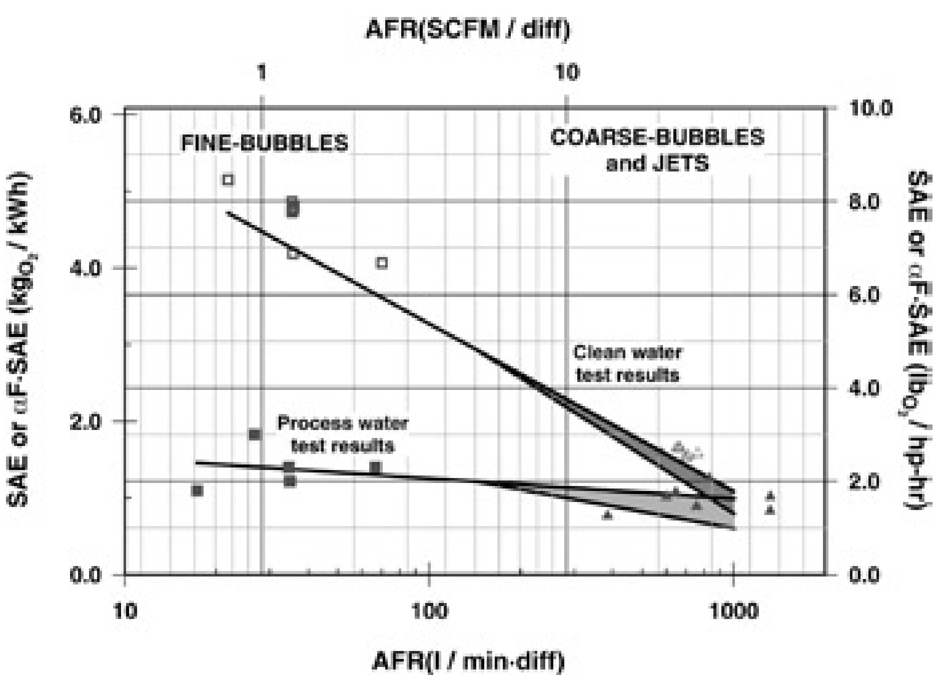


FIGURE 4 Standard Aeration Efficiency In Clean-(SAE) and Process-(αFSAE) Water for Fine-Pore and Coarse-Bubble Diffusers (data after Yunt and Stenstrom, 1996).



air flow rates, in general, correspond to lower aeration efficiency. This is because at higher air flow rate more energy per unit oxygen transferred is required to meet the uptake rate. Bubble surface-to-volume ratio improves at low air flow rates, where bubbles are formed with small diameters. Smaller bubbles also have lower rise velocity and increased time available for gas transfer. At low air flow rates, the bubbles are released with lower initial velocity, which further increases the time available for gas transfer. The shaded areas at high air flow rates represent the range of values that can be observed for coarse-bubbles, turbines, jets, or surface aerators. In general, turbines and jets tend to be at the top of the shaded range, while coarse-bubbles and surface aerators at the bottom. Note that for the same unit power required, the oxygen transferred by a fine-pore diffuser is typically about twice as great as can be obtained by coarse bubble diffusers, jets, turbines, or surface aerators.

Figure 5 shows the trend of a with increasing Reynolds Number (Re) and compares different aeration technologies in a series of laboratory-scale experiments. The Reynolds number is defined as:

$$(Re) = \frac{du}{v} \qquad (2)$$

where:

d = characteristic length,
for fine bubbles,
$$d = \frac{d_{eq}}{\phi}$$
for coarse bubbles,
d = bubble diameter

u = bubble rising velocity (L/T)

v = kinematic viscosity (L^2/T)

d_{eq} = diameter of the water column above the fine-bubble diffuser (L)

ϕ = volume fraction of liquid in the water column above the diffuser (-).

The trend lines in Figure 5 confirm the behavior of a versus turbulence predicted by Eckenfelder and Ford (1968). Figure 5 also shows the impact on clean water of 50mg/l of two different surfactants, a "fast" with high diffusivity (sodium dodecyl sulfate, m.w. ~ 10^2) such as rbCOD, and a "slow" with lower diffusivity (polyvinylpyrrolidone, m.w. ~ 10^4) surfactant. At this concentration, both surfactants were below the critical micelle concentration. The fast surfactant suppressed the transfer rate more because of its greater diffusion rate and greater accumulation at the bubble surface (lower trendline). This supression could be mitigated by the partial removal of rbCOD in the anoxic selector, before it has the chance to accumulate

FIGURE 5 The Effect of Turbulence on α Factors

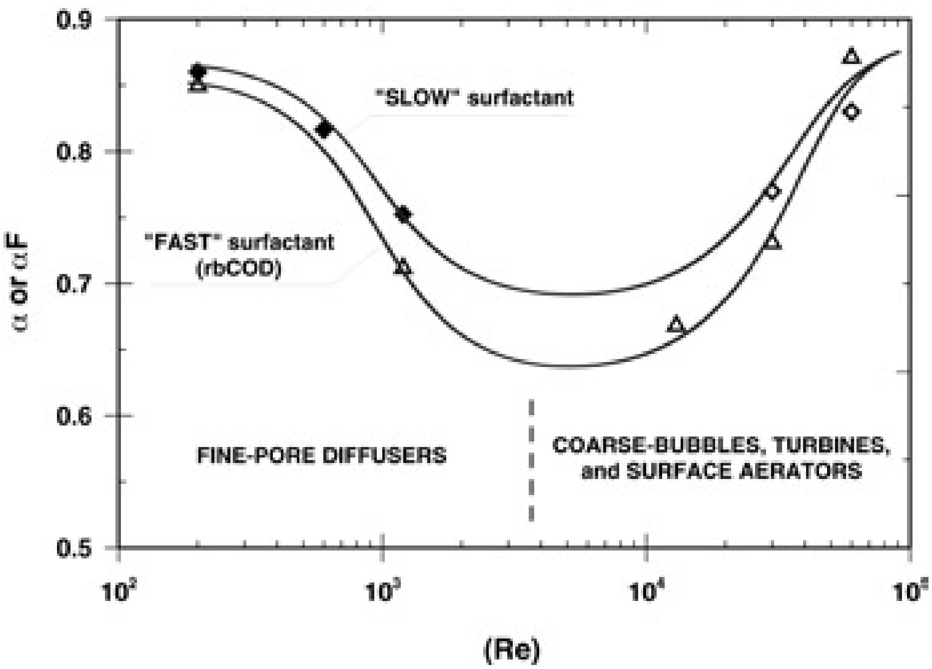


TABLE 1 Average values of off-gas tests for fine-pore and jet diffusers.

			AFR		αFSAE		αFSOTE	
Aerator	Bubbles	Water	(l/min-diff)	(scfm/diff)	(kg_{O2}/kWh)	(lb_{O2}/hp-hr)	(%)	(% ft)
Disks	Fine	Clean	39.8	1.40	4.72	7.76	30.7	2.05
Disks	Fine	Process	36.0	1.27	1.39	2.28	8.66	0.67
Jets	Fine	Clean	663	23.4	1.65	2.70	16.9	1.13
Jets	Fine	Process	756	26.7	1.01	1.66	9.50	0.63

onto fine-bubbles. The difference between slow and fast surfactants is much less for coarse-bubbles, turbines, jets, and surface aerators. This is because the very high interfacial velocity between air and liquid maintains the renewal of oxygen molecules at the liquid surface. This explains why fine-bubble diffusers have lower α factors. Note that even though the α factors are lower for fine-bubble diffusers, they are still more energy efficient, with αFSAE of 1.38 kg_{O2}/kWh as opposed to 1.00-0.70 kg_{O2}/kWh αSAE for all other aeration technology (see Figure 4). For reference, average values of αFSAE and αSAE for different aeration technologies are reported in Table 1. Also note that the fine-bubble data presented in Figure 4 are for a low density fine-pore diffuser system, and the more recently developed high density systems have higher SAE.

The central portion of the trend lines (i.e., where the curve is minimum) shows an interfacial flow regime that is usually not encountered in commercially available aeration systems. At extremely high energy densities (energy supplied per unit volume of water, or kWh/m^3), corresponding to (Re) > 10^5, the higher interfacial shear rate reduces the thickness of the interfacial film to a few layers of water molecules, and the phenomenon of liquid vaporization will be dominant, in a similar fashion to turbines or pumps cavitating. The far-right portion of the trend lines in Figure 5 corresponds to a region where mass transfer is affected by local energy density, corresponding to the shaded areas in Figure 4. In this region, (Re) and the energy density may be independent and produce different mass transfer rates. This means that high α factors can be achieved, at the expense of much reduced αSAE.

Figure 6 shows the results of 28 off-gas tests at plants that are low MCRT, carbon-only removal, nitrifying only and nitrifying-denitrifying (NDN, such as the MLE process). All values are flow-weighted averages over the entire tank area. This figure also shows the effect MCRT and diffuser condition (new, used, old, and cleaned) on transfer rate. Both diffuser condition and MCRT affect transfer rates. The average MCRT increased from approximately 5 days for conventional to approximately 15 days for both nitrifying and NDN treatment plants. The average α factor increases from 0.37 to 0.48 to 0.59 for conventional, nitrifying and NDN systems, respectively. The change in α from nitrifying to NDN can be attributed to the rbCOD removal in the selectors. Also note the effect of diffuser condition. Points in the upper range for each process are tests of new or recently cleaned diffusers (i.e., α factors), while the lower numbers are for used (< 24 months operation) and old (> 24 months) diffusers and include the impacts of fouling (i.e., αF factors).

Economic Considerations

To quantify the benefits of denitrification on plant economics, the major operating costs from the three types of plants were calculated. Oxygen requirements, aeration efficiency, sludge disposal cost, and digester biogas credit were considered. Other operating costs, such as labor cost, while still important, were not considered either because they play a minor role on plant energy costs, or because they do not vary significantly among the three process layouts.

The cost-analysis results for the three scenarios are reported in Table 2 in costs and credits per unit volume treated, both in metric and US customary units. The net cost was calculated as:

$$\text{NET COST} = \begin{pmatrix}\text{Aeration}\\ \text{cost}\end{pmatrix} + \begin{pmatrix}\text{Sludge disposal}\\ \text{cost}\end{pmatrix} - \begin{pmatrix}CH_4\text{ production}\\ \text{credit}\end{pmatrix} \quad (3)$$

These costs are based upon values that are typical for large municipal treatment plants (~ 100 MGD and larger), and implicitly include economies of scale. Care must be used when comparing these costs to small facilities, which typically have greater unit costs, due to the loss of economies of scale.

In order to calculate oxygen requirements and required airflow rate, a process temperature is 20°C and 2mg/l of dissolved oxygen (DO) was selected for all three scenarios (no aeration occurs in the anoxic zones). In order to adjust efficiency values to field conditions, a common depth of 5 m

FIGURE 6 Influence of Process Layout, MCRT and Diffuser Condition on α

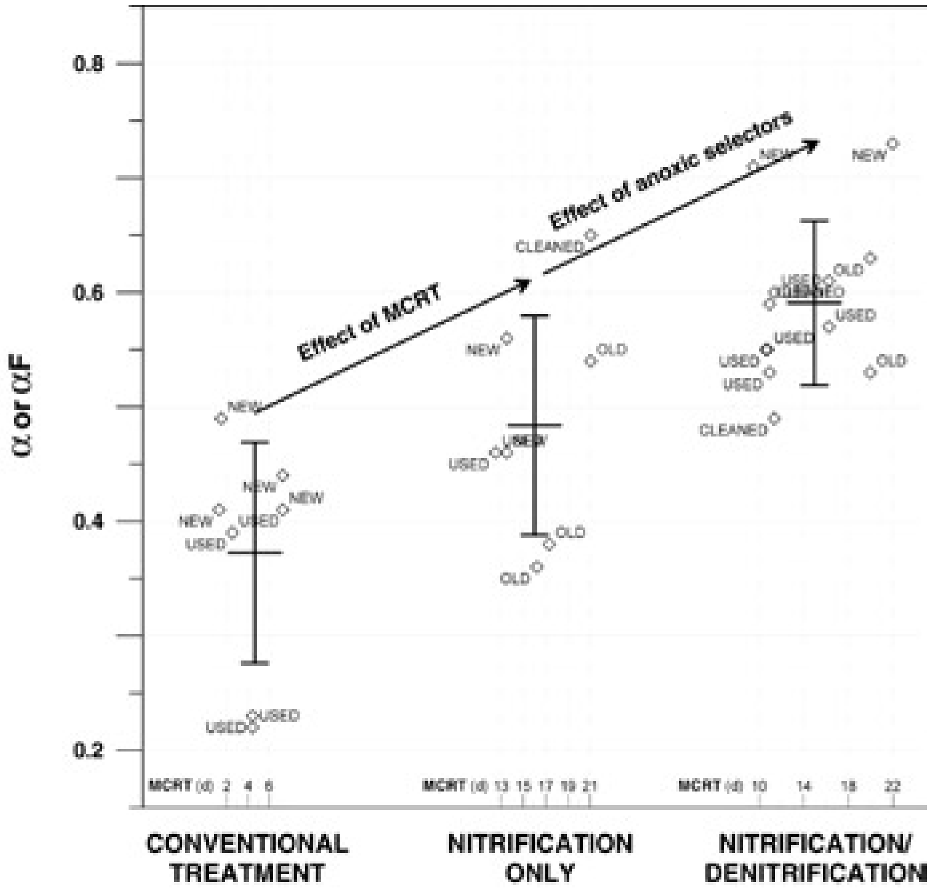


TABLE 2 Comparative Unit Costs and Requirements for Conventional Treatment, Nitrification Only, and Nitrification/Denitrification Processes.

	Conventional	Nitrifying-Only	Nitrifying/ Denitryfing
field transfer efficiency %	15.3	17.6	18.8
sludge disposal cost (USD/1000m^3)	7.0	3.9	3.5
O_2 requirement (kg$_{O2}$/1000m^3)	79	105	72
aeration cost (USD/1000m^3)	2.0	2.6	1.8
CH_4 production credit (USD/1000m^3)	4.8	1.8	1.6
net cost (USD/1000m^3)	4.2	4.7	3.7
sludge disposal cost (USD/MG)	26.5	14.7	13.0
O_2 requirement (lb$_{O2}$/MG)	659	872	601
aeration cost (USD/MG)	7.37	9.83	6.80
CH_4 production credit (USD/MG)	18.1	6.80	6.05
net cost (USD/MG)	15.7	17.8	13.8

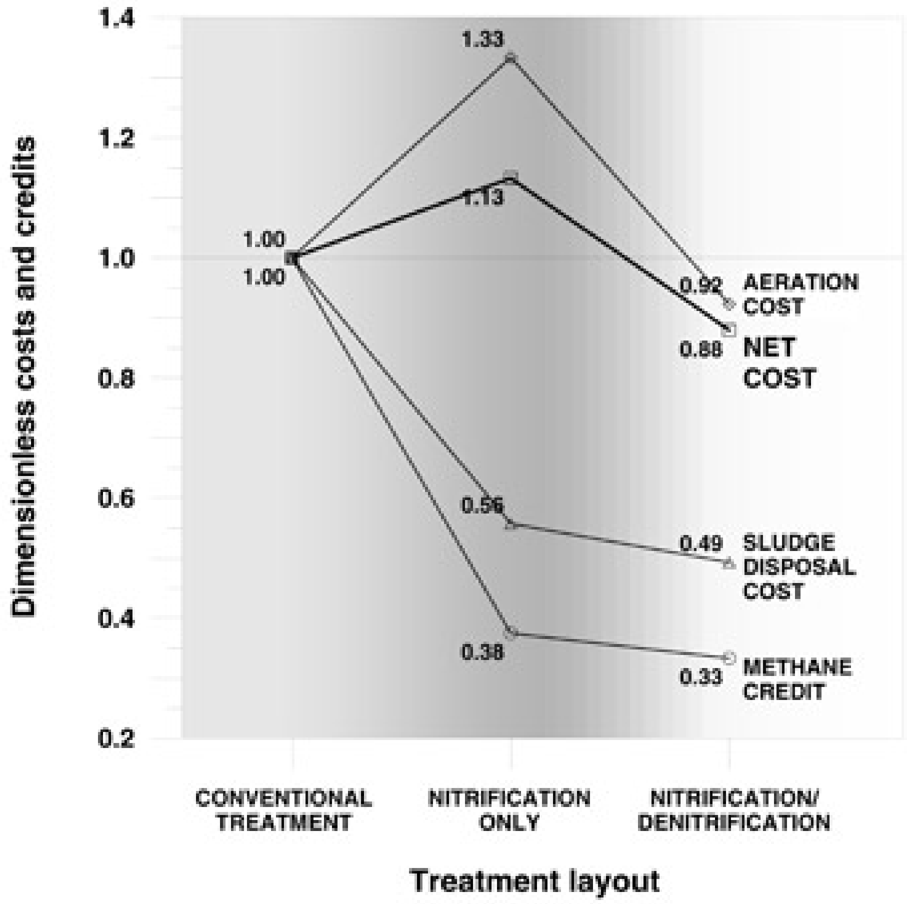
was assumed and an internal recirculation pump was included in the process layout. Note that, due to site-specific costs and requirements, the results reported in Table 2 should be used for comparison between the different layouts, and should be considered as sub-totals for each separate layout.

Nitrifying-only operations, with higher MCRT, result in higher oxygen requirements. However, higher MCRT operations are also associated with higher field transfer efficiencies. The results show a comparable airflow rate for conventional and NDN layout, this being due to the oxygen denitrification credit and to the higher efficiencies at higher MCRTs. The highest required airflow rate is for the nitrification-only layout, although the increase is not as much as the increase in oxygen requirement, due to the increased oxygen transfer efficiency. The minimum oxygen requirement, and therefore the minimum aeration burden and cost, occurs during NDN operation.

Sludge production values vary among layouts and are lowest for NDN operations. Therefore, assuming the digesters operating at the same retention time in all three cases, sludge disposal costs will be highest for conventional operations. Due to higher methane production yields, conventional operations will result in higher methane production. It is assumed that 50% VSS destruction occurs in the anaerobic digester and methane production ranges from 0.75 to 1.12 m^3/kg-VSS destroyed, the biogas composition is 65% methane on a dry basis, methane gas is valued at 5.4 \$/106 kJ (14 US cents per m^3, current methane value in Southern California), and 25% discount due to gas processing costs (scrubbing, adsorption, combustion, etc.), hence the final methane gas value is calculated as 0.06 \$/m^3 of biogas. The assumed sludge disposal cost is 20 \$/t$_{wet}$, and the calculated required blower energy is 1.17 kW/m^3. The power cost was assumed to be 0.15 \$/kWh, which is the typical cost for large treatment plants in the United States. The sum of costs minus credits is here referred to as net cost. Table 2 shows that NDN operations are the most cost-effective on the basis of net costs as well as aeration costs alone.

Costs, credits and their case combinations were normalized to relative ratios in order to eliminate currency or inflation effects (Figure 7). The costs for conventional operations were used as baseline; therefore, all relative costs and credits related to conventional operations amount to 1.00. In terms of net cost, nitrifying-only operations will be 1.13 times (113%) the net cost of conventional operations, while NDN will total 0.88 (88%) of conventional net cost. Aeration costs are highest for nitrifying-only operations, as expected. Costs and credits associated with solid-handling (i.e., sludge disposal cost and methane credit) have lower magnitude for nitrifying-only and NDN operations, due to the smaller amounts of sludge produced per unit time.

FIGURE 7 Relative Costs and Credits for Conventional Treatment, Nitrification Only, and NDN Processes.



Design Recommendations

Our analysis was restricted to operating costs. A detailed analysis of potential changes in process sizes is beyond the scope of this paper. However, depending on the local plant situation, expansion of aeration volume and/or clarifier area might be necessary, and the operating savings could be offset by debt service on plant expansion.

The change from conventional to NDN mode requires increased MCRT, which will necessitate retaining higher mixed-liquor suspended solids (MLSS) mass in the aeration tank. This may be achieved with greater aeration tank volume or higher MLSS concentrations, resulting in higher solids flux to the secondary clarifiers. Note that the increased MLSS concentrations to achieve NDN in an activated sludge process are not expected to impact α. The typical MLSS concentrations for the processes discussed here (2-4 g/l) are much lower than concentrations used in membrane bioreactors (8-20 g/l), which have demonstrated low α factors ($\alpha = 0.4$ at $17 g_{MLSS}/l$) due to viscous transport limitations (Wagner, et al., 2002). The retrofit to NDN operations typically creates better settling sludge (Harper and Jenkins, 2003), which increases the limiting secondary clarifier solids flux. The actual capital improvements required to support higher MLSS mass will be different for each plant, and are too site-specific to be quantified here. Several agencies in Southern California have found that no additional tank volume was required, due to the elevated temperatures and to the use of reserve capacity included in conservative designs.

The design and construction of the baffle separating anoxic and aerated zone to prevent scum accumulation is important for "healthy" plant operations. Figure 8 shows a schematic of the baffle's hydraulic requirements. The anoxic tank water level should always have a hydraulic gradient to the aerated zone, i.e. the water level in the anoxic zone should be at least higher than the aerated zone in operation (this must include the expansion due to the bubble volume, typically 4 to 6 inches for a 15 ft deep tank). An opening between the baffle bottom and the tank bottom allows enough flow to guarantee proper hydraulic transit of the wastewater, and ease in draining the tanks for maintenance.

Implications of baffling on foaming and foam selection are shown in Figure 9. The figure on the left shows a conventional treatment (MCRT = 1.2 days) during an off-gas testing. In this case, the foam is so thick (~2ft !) that completely obscures the off-gas hood. The figure in the center shows a treatment plant with an anoxic selector, but with poor baffle design/construction: the hydraulic gradient between the anoxic and aerated zones is not sufficient, and the net result is foam flowing backwards into the anoxic tank (the dark surface in the center of the image, i.e. where the tank is equipped with surface mixers). This selects for foam-forming organisms, and requires periodic manual removal of the foam. The figure on the right shows a correctly designed and constructed baffle: the hydraulic gradient is sufficient, and no foam is retained in the selector zone. The baffle functions as a submerged weir. During these "healthy" operations, the foam and foam-forming organisms are continuously wasted into the aerobic tank, and not allowed to accumulate. This increases the sustainability of the process, as well as reducing labor costs associated with periodic manual foam disposal.

SUMMARY AND CONCLUSIONS

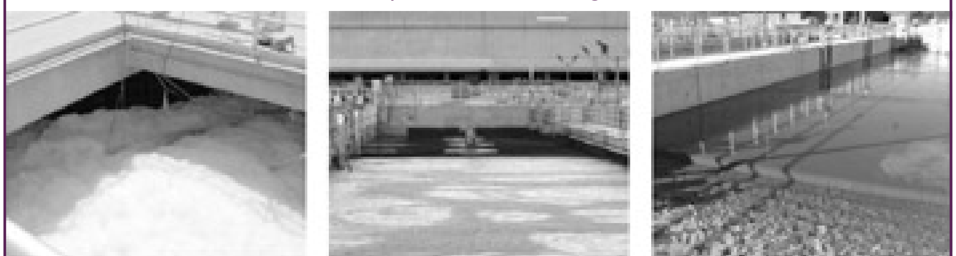
The activated sludge process, operated with anoxic selectors has several operational advantages:

- Improved nitrogen removal
- Increased stability of biological treatment operations
- Improved removal of recalcitrant COD
- Advantageous economics due to oxygen credit and higher OTE

We tested 22 treatment plants which included either conventional, nitrifying-only, or nitrifying-denitrifying (NDN) operations. The average oxygen transfer efficiency for NDN operations was consistently higher. This is because the rapidly

FIGURE 8 Requirements for Correct Baffle Design and Construction

FIGURE 9 Baffle Installation and Its Implications on Foaming and Foam Selection



CONVENTIONAL TREATMENT: Low DO; no chance for surfactants to be removed before accumulating onto bubbles; high propensity for foaming and filamentous growth.

NITRIFICATION/DENITRIFICATION: Retention of scum and filamentous organisms [dark, in the center] within the anoxic zone, due to improper baffle design and construction.

NITRIFICATION/DENITRIFICATION: The image above shows no retention of scum and filamentous organisms in the anoxic tank, due to correct baffle design and construction.

degradable COD (i.e., the rbCOD) may be removed in the anoxic selector and used by the denitrifiers for nitrate conversion. This fraction of rbCOD would otherwise accumulate onto fine-bubbles in the aerated zone, with dramatic reduction of oxygen transfer efficiency and severely increased plant operating costs. Our economic analyses quantify and show that NDN has lowest operating costs, when compared to conventional and nitrifying-only operations. Capital costs were not included in this analysis. Depending on the local plant situation, expansion of aeration volume and/or clarifier area might be necessary, and the operating savings could be offset by debt service on plant expansion.

New designs and upgrades should consider the benefits of operating in NDN mode, even if the permit does not require nitrogen removal. During the initial stages of a plant operation, the plant is typically underloaded, benefiting of the spare capacity available for operating in NDN mode. The designer should always consider the economic benefit of operating in NDN mode during the initial years. The initial design requirements to include NDN (e.g., mixers, anoxic zones, baffles, etc.) can be included, in most cases, with marginal additional costs, and will in the long run save substantial amounts of operating costs. The overall conclusion is that design engineers and plant owners should no longer assume that NDN operation will always be more expensive than conventional, low MCRT operation.

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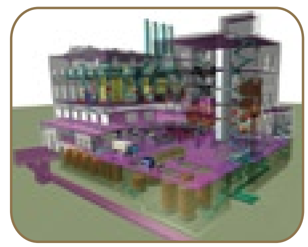

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